



US009670254B2

(12) **United States Patent**
Norris

(10) **Patent No.:** **US 9,670,254 B2**
(45) **Date of Patent:** **Jun. 6, 2017**

(54) **VMP-LIKE SEQUENCES OF PATHOGENIC
BORRELIA SPECIES AND STRAINS**

(71) Applicant: **BOARD OF REGENTS, THE
UNIVERSITY OF TEXAS SYSTEM,**
Austin, TX (US)

(72) Inventor: **Steven J. Norris,** Houston, TX (US)

(73) Assignee: **BOARD OF REGENTS OF THE
UNIVERSITY OF TEXAS SYSTEM,**
Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/804,882**

(22) Filed: **Jul. 21, 2015**

(65) **Prior Publication Data**

US 2016/0102124 A1 Apr. 14, 2016

Related U.S. Application Data

(60) Continuation of application No. 14/257,613, filed on
Apr. 21, 2014, now Pat. No. 9,115,193, which is a
continuation of application No. 13/645,950, filed on
Oct. 5, 2012, now Pat. No. 8,722,871, which is a
division of application No. 13/324,357, filed on Dec.
13, 2011, now Pat. No. 8,283,458, which is a division
of application No. 12/962,154, filed on Dec. 7, 2010,
now Pat. No. 8,076,470, which is a division of
application No. 10/539,956, filed as application No.
PCT/US03/41182 on Dec. 22, 2003, now Pat. No.
7,847,084.

(60) Provisional application No. 60/435,077, filed on Dec.
20, 2002.

(51) **Int. Cl.**

A61K 39/02 (2006.01)
A61K 39/00 (2006.01)
G01N 33/53 (2006.01)
C07K 14/20 (2006.01)
G01N 33/569 (2006.01)
C07K 17/08 (2006.01)
C07K 17/12 (2006.01)
C08G 69/48 (2006.01)
G01N 33/68 (2006.01)

(52) **U.S. Cl.**

CPC **C07K 14/20** (2013.01); **C07K 17/08**
(2013.01); **C07K 17/12** (2013.01); **C08G 69/48**
(2013.01); **G01N 33/569II** (2013.01); **G01N**
33/6854 (2013.01); **A61K 39/00** (2013.01);
A61K 39/02 (2013.01); **G01N 2333/20**
(2013.01); **G01N 2469/20** (2013.01); **G01N**
2800/26 (2013.01)

(58) **Field of Classification Search**

CPC **A61K 39/00**; **A61K 39/02**; **G01N 33/00**
USPC **424/184.1**, **185.1**, **234.1**; **435/4**, **7.1**, **7.2**
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,554,101 A	11/1985	Hopp	530/324
4,578,770 A	3/1986	Mitani	250/559.2
4,596,792 A	6/1986	Vyas	
4,599,230 A	7/1986	Milich et al.	424/189.1
4,599,231 A	7/1986	Milich et al.	424/189.1
4,601,903 A	7/1986	Frasch	424/250.1
4,608,251 A	8/1986	Mia	424/185.1
4,721,617 A	1/1988	Johnson	424/234.1
4,801,540 A	1/1989	Hiatt et al.	435/411
5,155,022 A	10/1992	Naqui et al.	435/7.32
5,178,859 A	1/1993	Simon et al.	435/139.1
5,187,065 A	2/1993	Schutzer	435/7.32
5,217,872 A	6/1993	Dorward et al.	435/7.32
5,217,874 A	6/1993	Guadagno et al.	435/28
5,246,844 A	9/1993	Norris et al.	435/480
5,279,938 A	1/1994	Rosa	435/6
5,283,175 A	2/1994	Weaver et al.	435/6
5,304,718 A	4/1994	Ward et al.	800/266
5,324,630 A	6/1994	LeFebvre et al.	435/6
5,385,826 A	1/1995	Schell et al.	435/7.32
5,434,077 A	7/1995	Simon et al.	435/243
5,436,000 A	7/1995	Barbour et al.	424/93.2
5,571,718 A	11/1996	Dunn et al.	435/252.3
6,437,116 B1	8/2002	Norris et al.	536/23.7
6,475,492 B1	11/2002	Philipp et al.	424/234.1
6,610,301 B1	8/2003	Motz et al.	424/190.1
6,660,274 B2	12/2003	Philipp	424/234.1
6,719,983 B2	4/2004	Norris et al.	536/23.1
6,740,744 B2	5/2004	Norris et al.	536/23.1

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 91/13630 9/1991
WO WO 97/31123 8/1997

(Continued)

OTHER PUBLICATIONS

“Borrelia afzelii strain ACAI clone 2622 VLsE (vlsE) mRNA,
partial cds,” XP002679764, database accession No. AY100629,
Mar. 19, 2003.

(Continued)

Primary Examiner — Rodney P Swartz

(74) *Attorney, Agent, or Firm* — Parker Highlander PLLC

(57) **ABSTRACT**

The present invention relates to DNA sequences encoding
Vmp-like polypeptides of pathogenic *Borrelia*, the use of the
DNA sequences in recombinant vectors to express polypep-
tides, the encoded amino acid sequences, application of the
DNA and amino acid sequences to the production of poly-
peptides as antigens for immunoprophylaxis, immuno-
therapy, and immunodiagnosis. Also disclosed are the use of
the nucleic acid sequences as probes or primers for the
detection of organisms causing Lyme disease, relapsing
fever, or related disorders, and kits designed to facilitate
methods of using the described polypeptides, DNA seg-
ments and antibodies.

8 Claims, 16 Drawing Sheets

(56)

References Cited

U.S. PATENT DOCUMENTS

6,878,816	B2	4/2005	Norris et al.	536/23.1
7,135,176	B2	11/2006	Norris et al.	424/139.1
7,847,084	B2	12/2010	Norris et al.	536/23.7
8,076,470	B2	12/2011	Norris et al.	536/23.7
8,283,458	B2	10/2012	Norris	536/23.7
2007/0117970	A1	5/2007	Norris et al.	424/185.1
2013/0102057	A1	4/2013	Norris	536/23.7

FOREIGN PATENT DOCUMENTS

WO	WO 99/00413	1/1999
WO	WO 00/65064	11/2000

OTHER PUBLICATIONS

Balmelii and Piffatetti, "Analysis of the genetic polymorphism of *Borrelia burgdorferi* sensu lato by multilocus enzyme electrophoresis," *Int. J. Syst. Bacteriol.*, 46:167-172, 1996.

Barbour and Garon, "Linear plasmids of the bacterium *Borrelia burgdorferi* have covalently closed ends," *Science*, 237:409-411, 1987.

Barbour et al., "Structural analysis of the variable major proteins of *Borrelia hermsii*," *J. Exp. Med.*, 158:2127-2140, 1983.

Barbour et al., "Tandem insertion sequence-like elements define the expression site for variable antigen genes of *Borrelia hermsii*," *Infect. Immun.*, 59:390-397, 1991.

Barbour et al., "Variable antigen genes of the relapsing fever agent *Borrelia hermsii* are activated by promoter addition," *Mol. Microbiol.*, 5:489-493, 1991.

Barbour et al., "Variable major proteins of *Borrelia hermsii*," *J. Exp. Med.*, 156:1312-1324, 1982.

Barbour, "Immunochemical analysis of Lyme disease spirochetes," *Yale J. Biomed.*, 57:581-586, 1984.

Barbour, "Plasmid analysis of *Borrelia burgdorferi*, the Lyme disease agent," *J. Clin. Microbiol.*, 26(3):475-478, 1988.

Barstad et al., "Variable major proteins of *Borrelia hermsii*. Epitope mapping and partial sequence analysis of CNBr peptides," *J. Exp. Med.*, 161:1302-1314, 1985.

Barthold et al., "Susceptibility of laboratory rats to isolates of *Borrelia burgdorferi* from different geographic areas," *Am. J. Trop. Med. Hyg.*, 42:596-600, 1990.

Barthold, "Antigenic stability of *Borrelia burgdorferi* during chronic infections of immunocompetent mice," *Infect. Immun.*, 61:4955-4961, 1993.

Benach et al., "A murine IgM monoclonal antibody binds an antigenic determinant in outer surface protein A, an immunodominant basic protein of the Lyme disease spirochete," *The Journal of Immunology*, 140:265-272, 1988.

Brandt et al., "Immunogenic integral membrane proteins of *Borrelia burgdorferi* are lipoproteins," *Infect. Immun.*, 58(4):983-991, 1990.

Burgdorfer et al., "Lyme disease, a tick-borne spirochetosis?," *Science*, 216:1317-1319, 1982.

Burman et al., "The variable antigens Vmp7 and Vmp21 of the relapsing fever bacterium *Borrelia hermsii* are structurally analogous to the VSG proteins of the African trypanosome," *Molecular Microbiology*, 4(10):1715-1726, 1990.

Cadavid et al., "Variability of a bacterial surface protein and disease expression in a possible mouse model of systemic Lyme borreliosis," *J. Exp. Med.*, 179(2):631-42, 1994.

Carroll and Gheradini, "Membrane protein variations associated with in vitro passage of *Borrelia burgdorferi*," *Infect. Immun.*, 64:392-398, 1996.

Carter et al., "A family of surface-exposed proteins of 20 kilodaltons in the genus *Borrelia*," *Infect. Immun.*, 62:2792-2799, 1994.

Casjens et al., "Linear chromosomes of Lyme disease agent spirochetes: genetic diversity and conservation of gene order," *J. Bacteriol.*, 177:2769-2780, 1995.

Cluss and Boothby, "Thermoregulation of protein synthesis in *Borrelia burgdorferi*," *Infect. Immun.*, 58(4):1038-1042, 1990.

Database UniProt Online, "Complement C3 precursor (HSE-MSF) 'Contains: Complement C3 beta chain; Complement C3 alpha chain; C3a anaphylatoxin Complement C3b alpha' chain; Complement C3c fragment; Complement C3dg fragment; Complement C3g fragment; Complement C3d fragment; Complement C, isoform Short; C3f fragment!." 671 7," Database Accession No. P01027, 1986.

Dever et al., "In vitro antimicrobial susceptibility testing of *Borrelia burgdorferi*: a microdilution MIC method and time-kill studies," *J. Clin. Microbiol.*, 30:2692-2697, 1992.

Donelson, "Mechanisms of antigenic variation in *Borrelia hermsii* and African trypanosomes," *J. Biol. Chem.*, 270:7781-7786, 1995. Extended European Search Report and Search Opinion issued in European Application No. 10011690.4, mailed Nov. 13, 2012.

Fawcett et al., "Detection of antibodies to the recombinant p39 protein of *Borrelia burgdorferi* using enzyme immunoassay and immunoblotting," *J. Rheumatology*, 20(4):734-738, 1993.

Fuchs et al., "Molecular analysis and expression of a *Borrelia burgdorferi* gene encoding a 22kDa protein (pC) in *E. coli*," *Mol. Microbiol.*, 6:503-509, 1992.

GenBank Accession No. AAB09432, 1996.

GenBank Accession No. AAB17737, 1996.

GenBank Accession No. AAC45733, 1997.

Grodzicki and Steere, "Comparison of immunoblotting and indirect enzyme-linked immunosorbent assay using different antigen preparations for diagnosing early Lyme disease," *J. Infect. Dis.*, 157(4):790-797, 1988.

Hagblom et al., "Intragenic recombination leads to pilus antigenic variation in *Neisseria gonorrhoeae*," *Nature*, 315:156-158, 1985.

Howe et al., "A single recombinant plasmid expressing two major outer surface proteins of the Lyme disease spirochete," *Science*, 227:645-646, 1985.

Howe et al., "Organization of genes encoding two outer membrane proteins of the Lyme disease agent *Borrelia burgdorferi* within a single transcriptional unit," *Infect. Immun.*, 54:207-212, 1986.

Hudson et al., "Increased expression of *Borrelia burgdorferi* vlsE in response to human endothelial cell membrane," *Mol. Microbiol.*, 41:229-239, 2001.

Hughes and Johnson, "Methylated DNA in *Borrelia* species," *J. Bacteriol.*, 172:6602-6604, 1990.

Hyde et al., "Detection of antigens in urine of mice and human infected with *Borrelia burgdorferi*, etiologic agent of Lyme disease," *Journal of Clinical Microbiology*, 27(1):58-61, 1989.

Indest et al., "Analysis of *Borrelia burgdorferi* vlsE gene expression and recombination in the tick vector," *Infect. Immun.*, 69:7083-7090, 2001.

Jiang et al., "Cross-antigenicity between the major surface proteins (ospA and ospB) and other proteins of *Borrelia burgdorferi*," *J. Immun.*, 144(1):284-289, 1990.

Johnson et al., "Infection of Syrian hamsters with Lyme disease spirochetes," *J. Clin. Microbiol.*, 20:1099-1101, 1984.

Karlsson, "Western immunoblot and flagellum enzyme-linked immunosorbent assay for serodiagnosis of Lyme borreliosis," *J. Clin. Microbiol.*, 28(9):2148-2150, 1990.

Kawabata et al., "Genetic and immunological analyses of Vls (VMP-like sequence) of *Borrelia burgdorferi*," *Microbial Pathogenesis*, 24:155-165, 1998.

Kitten and Barbour, "Juxtaposition of expressed variable antigen genes with a conserved telomere in the bacterium *Borrelia hermsii*," *Proc. Natl. Acad. Sci. USA*, 87:6077-6081, 1990.

Kitten and Barbour, "The relapsing fever agent *Borrelia hermsii* has multiple copies of its chromosome and linear plasmids," *Genetics*, 132:311-324, 1992.

Kitten et al., "Intragenic recombination and a chimeric outer membrane protein in the relapsing fever agent *Borrelia hermsii*," *J. Bacteriol.*, 175(9):2516-2522, 1993.

Koomey et al., "Effects of *recA* mutations on pilus antigenic variation and phase transitions in *Neisseria gonorrhoeae*," *Genetics*, 117:391-398, 1987.

Kupsch et al., "Variable opacity (Opa) outer membrane proteins account for the cell tropisms displayed by *Neisseria gonorrhoeae* for human leukocytes and epithelial cells," *EMBO. J.*, 12:641-650, 1993.

(56)

References Cited

OTHER PUBLICATIONS

- Lambden et al., "Biological properties of two distinct pilus types produced by isogenic variants of *Neisseria gonorrhoeae* P9," *J. Bacteriol.*, 141:393-396, 1980.
- LeFebvre et al., "Characterization of *Borrelia burgdorferi* isolates by restriction endonuclease analysis and DNA hybridization," *Journal of Clinical Microbiology*, 27(4):636-639, 1989.
- Liang and Philipp., "Analysis of antibody response to invariable regions of VlsE, the variable surface antigen of *Borrelia burgdorferi*," *Infect. Immun.*, 67:6702-6706, 1999.
- Liang et al., "Antigenic conservation of an immunodominant invariable region of the LvsE lipoprotein among European pathogenic genospecies of *Borrelia burgdorferi* SL," *J. Infect. Dis.*, 182:1455-1462, 2000.
- Liang et al., "An immunodominant conserved region within the variable domain of VlsE, the variable surface antigen of *Borrelia burgdorferi*," *J. Immunol.*, 163:5566-5573, 1999.
- Liang et al., "Characterization of a *Borrelia burgdorferi* VlsE invariable region useful in canine lyme disease serodiagnosis by enzyme-linked immunosorbent assay," *J. Clinical Microbiology*, 38(11):4160-4166, 2000.
- Liang et al., "Sensitive and specific serodiagnosis of lyme disease by enzyme-linked immunosorbent assay with a peptide based on an immunodominant conserved region of *Borrelia burgdorferi* VlsE," *J. Clinical Microbiol.*, 37(12):3990-3996, 1999.
- Livey et al., "Evidence for lateral transfer and recombination in PspC variation in Lyme disease *Borrelia*," *Mol. Microbiol.*, 18:257-269, 1995.
- Luft et al., "Biochemical and immunological characterization of the surface proteins of *Borrelia burgdorferi*," *Infect. Immun.*, 57(11):3637-3645, 1989.
- Marconi et al., "Analysis of the distribution and molecular heterogeneity of the ospD gene among the Lyme disease spirochetes: evidence for lateral gene exchange," *J. Bacteriol.*, 176:4572-4582, 1994.
- Marconi, et al., "Variability of osp genes and gene products among species of Lyme disease spirochetes," *Infect. Immun.*, 61:2611-2617, 1993.
- Margolis et al., "Homology between *Borrelia burgdorferi* OspC and members of the family of *Borrelia hermsii* variable major proteins," *Gene*, 143:105-110, 1994.
- Moody et al., "Lyme borreliosis in laboratory animals: effect of host species and in vitro passage of *Borrelia burgdorferi*," *Am. J. Trop. Med. Hyg.*, 43(1):87-92, 1990.
- Norris et al., "High- and low-infectivity phenotypes of clonal populations of in vitro-cultured *Borrelia burgdorferi*," *Infect. Immun.*, 63:2206-2212, 1995.
- Norris et al., "Low-passage-associated proteins of *Borrelia burgdorferi* B31: characterization and molecular cloning of OspD, a surface-exposed, plasmid-encoded lipoprotein," *Infect. Immun.*, 60:4662-4672, 1992.
- Office Action issued in European Application No. 03 800 145.9, mailed Jul. 9, 2008.
- Office Action issued in European Application No. 03 800 145.9, mailed Mar. 22, 2010.
- Office Action issued in European Application No. 03 800 145.9, mailed Dec. 6, 2006.
- Office Action issued in European Application No. 10 011 690.4, mailed Dec. 5, 2013.
- Office Action issued in U.S. Appl. No. 10/539,956, mailed Jun. 16, 2009.
- Office Action issued in U.S. Appl. No. 10/539,956, mailed Jun. 23, 2008.
- Office Action issued in U.S. Appl. No. 10/539,956, mailed Mar. 31, 2010.
- Office Action issued in U.S. Appl. No. 12/962,154, mailed Mar. 25, 2011.
- Office Action issued in U.S. Appl. No. 13/324,357, mailed Jan. 27, 2012.
- Office Action issued in U.S. Appl. No. 13/645,950, mailed Jan. 30, 2013.
- PCT International Search Report issued in International Application No. PCT/US03/41182, mailed Oct. 15, 2004.
- Pennington et al., "Arthritis severity and spirochete burden are determined by serotype in the *Borrelia turicatae*-mouse model of Lyme disease," *Infect Immunology*, 65(1):285-92, 1997.
- Persing et al., "Genetic stability of *Borrelia burgdorferi* recovered from chronically infected immunocompetent mice," *Infect. Immun.*, 62:3521-3527, 1994.
- Plasterk et al., "Transposition of structural genes to an expression sequence on a linear plasmid causes antigenic variation in the bacterium *Borrelia hermsii*," *Nature*, 318:257-263, 1985.
- Purser and Norris, "Correlation between plasmid content and infectivity in *Borrelia burgdorferi*," *Proc. Natl. Acad. Sci. USA*, 97:13865-13870, 2000.
- Restrepo and Barbour, "Antigen diversity in the bacterium *B. hermsii* through 'somatic' mutations in rearranged *vmp* genes," *Cell*, 78:867-876, 1994.
- Restrepo et al., "Activation of a *vmp* pseudogene in *Borrelia hermsii*: an alternate mechanism of antigenic variation during relapsing fever," *Mol. Microbiol.*, 13:287-299, 1994.
- Restrepo et al., "Subtelomeric expression regions of *Borrelia hermsii* linear plasmids are highly polymorphic," *Mol. Microbiol.*, 6:3299-3311, 1992.
- Rosa et al., "Directed insertion of a selectable marker into a circular plasmid of *Borrelia burgdorferi*," *J. Bacteriol.*, 178:5946-5953, 1996.
- Rosa et al., "Recombination between genes encoding major surface proteins A and B of *Borrelia burgdorferi*," *Mol. Microbiol.*, 6:3031-3040, 1992.
- Sadziene et al., "Antibody-resistant mutations of *Borrelia burgdorferi*: in vitro selection and characterization," *J. Exp. Med.*, 176:799-809, 1992.
- Sadziene et al., "*Borrelia burgdorferi* mutant lacking osp: biological and immunological characterization," *Infection and Immunity*, 63(4):1573-1580, 1995.
- Saniuels, et al., "Genetic transformation of the Lyme disease agent *Borrelia burgdorferi* with coumarin-resistant *gyrB*," *J. Bacteriol.*, 176:6045-6049, 1994.
- Schwan and Simpson, "Factors influencing the antigenic reactivity of *Borrelia burgdorferi* the Lyme disease spirochete," *Scand. J. Infect. Dis.*, 77:94-101, 1991.
- Schwan et al., "Changes in antigenic reactivity of *Borrelia burgdorferi* the Lyme disease spirochete, during persistent infection in mice," *Can. J. Microbiol.*, 37:450-454, 1991.
- Schwan et al., "Changes in infectivity and plasmid profile of the Lyme disease spirochete, *Borrelia burgdorferi*, as a result of in vitro cultivation," *Infect. Immun.*, 56:1831-1836, 1988.
- Scriba et al., "The 39-kilodalton protein of *Borrelia burgdorferi*: a target for bactericidal human monoclonal antibodies," *Infect. Immun.*, 61(10):4523-4526, 1993.
- Segal et al., "Antigenic variation of gonococcal pilus involves assembly of separated silent gene segments," *Proc. Natl. Acad. Sci. USA*, 83:2177-2181, 1986.
- Seifert and So, "Genetic mechanisms of bacterial antigenic variation," *Microbiol. Rev.*, 52:327-336, 1988.
- Simpson et al., "Reactivity of human Lyme borreliosis sera with a 39-kilodalton antigen specific to *Borrelia burgdorferi*," *J. Clin. Microbiol.*, 28(6):1329-1337, 1990.
- Simpson et al., "Antibody to a 39-kilodalton *Borrelia burgdorferi* antigen (P39) as a marker for infection in experimentally naturally inoculated animals," *J. Clinical Microb.*, 29(2):236-243, 1991.
- Stevenson et al., "Expression and gene sequence of outer surface protein C of *Borrelia burgdorferi* reisolated from chronically infected mice," *Infect. Immun.*, 62:3568-3571, 1994.
- Stoener et al., "Antigenic variation of *Borrelia hermsii*," *J. Exp. Med.*, 156:1297-1311, 1982.
- Supplementary European Search Report issued in European Application No. 03 800 145.9, mailed Apr. 21, 2006.
- Szczepanski and Benach, "Lyme borreliosis: host responses to *Borrelia burgdorferi*," *Microb. Rev.*, 55(1):21-34, 1991.

(56)

References Cited

OTHER PUBLICATIONS

- Thiessen et al., "Evolution of the *Borrelia burgdorferi* outer surface protein OspC," *J. Bacterio.*, 177:3036-3044, 1995.
- Walker et al., "Physical map of the genome of *Treponema pallidum* subsp. *pallidum* (Nichols)," *J. Bacteriol.*, 177 :1797-1804, 1995.
- Wallich et al., "The *Borrelia burgdorferi* flagellum-associated 41-kilodalton antigen (flagellin): molecular cloning, expression and amplification of the gene," *Infect. Immun.*, 58(6):1711-1719, 1990.
- Wang et al., "Analysis of a VMP-like sequence (vls) locus in *Borrelia garinii* and Vls homologues among four *Borrelia burgdorferi* sensu lato species," *FEMS Microbiol. Lett.*, 199:39-45, 2001.
- Wang et al., "Characterization of the vls antigenic variation loci of the Lyme disease spirochaetes *Borrelia garinii* Ip90 and *Borrelia afzelii* ACAI," *Molecular Microbiology*, 47(5):1407-17, 2003.
- Wang, et al., "Characteristics of the vls Locus of *Borrelia garinii* Ip90," Abstracts of the General Meeting of the American Society for Microbiology 100th General Meeting, 100:275, 2000.
- Wilske et al., "Antigenic variation and strain heterogeneity in *Borrelia* spp.," *Res. Microbiol.*, 143:583-596, 1992.
- Wise and Weaver, "Detection of the lyme disease bacterium, *Borrelia burgdorferi*, by using the polymerase chain reaction and a nonradioisotopic gene probe," *Journal of Clinical Microbiology*, 29(7):1523-1526, 1991.
- Wu and Tokunaga, "Biogenesis of lipoproteins in bacteria," *Curr. Top. Microbiol. Immunol.*, 125:127-157, 1986.
- Xu and Johnson, "Analysis and comparison of plasmid profile of *Borrelia burgdorferi* sensu lato strains," *J. Clin. Microbiol.*, 3:3:2079-2685, 1995.
- Xu et al., "Correlation of plasmids with infectivity: of *Borrelia burgdorferi* sensu stricto type strain B31," *Infect. Immun.*, 64:3870-3876, 1996.
- Zhang and Norris, "Genetic variation of the *Borrelia burgdorferi* gene vlsE involves cassette-specific, segmental gene conversation," *Infect. Immun.*, 66:3698-3704, 1998.
- Zhang and Norris, "Kinetics and in vitro induction of genetic variation of vlsE in *Borrelia burgdorferi*," *Infect. Immun.*, 66:3689-3697, 1998.
- Zhang et al., "Antigenic variation in lyme disease borreliae by promiscuous recombination of VMP-like sequence cassettes," *Cell*, 89:275-285, 1997.

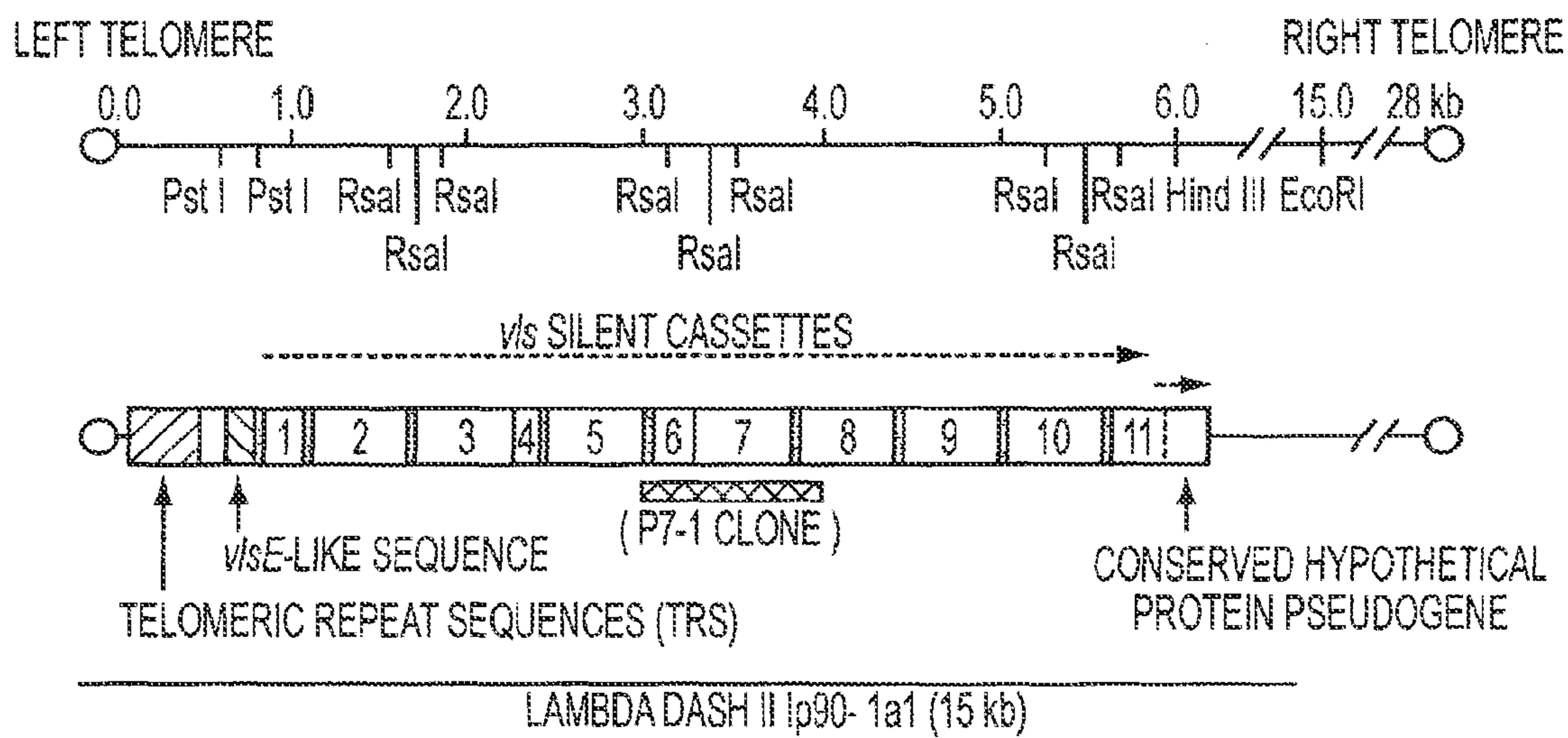


FIG. 1A

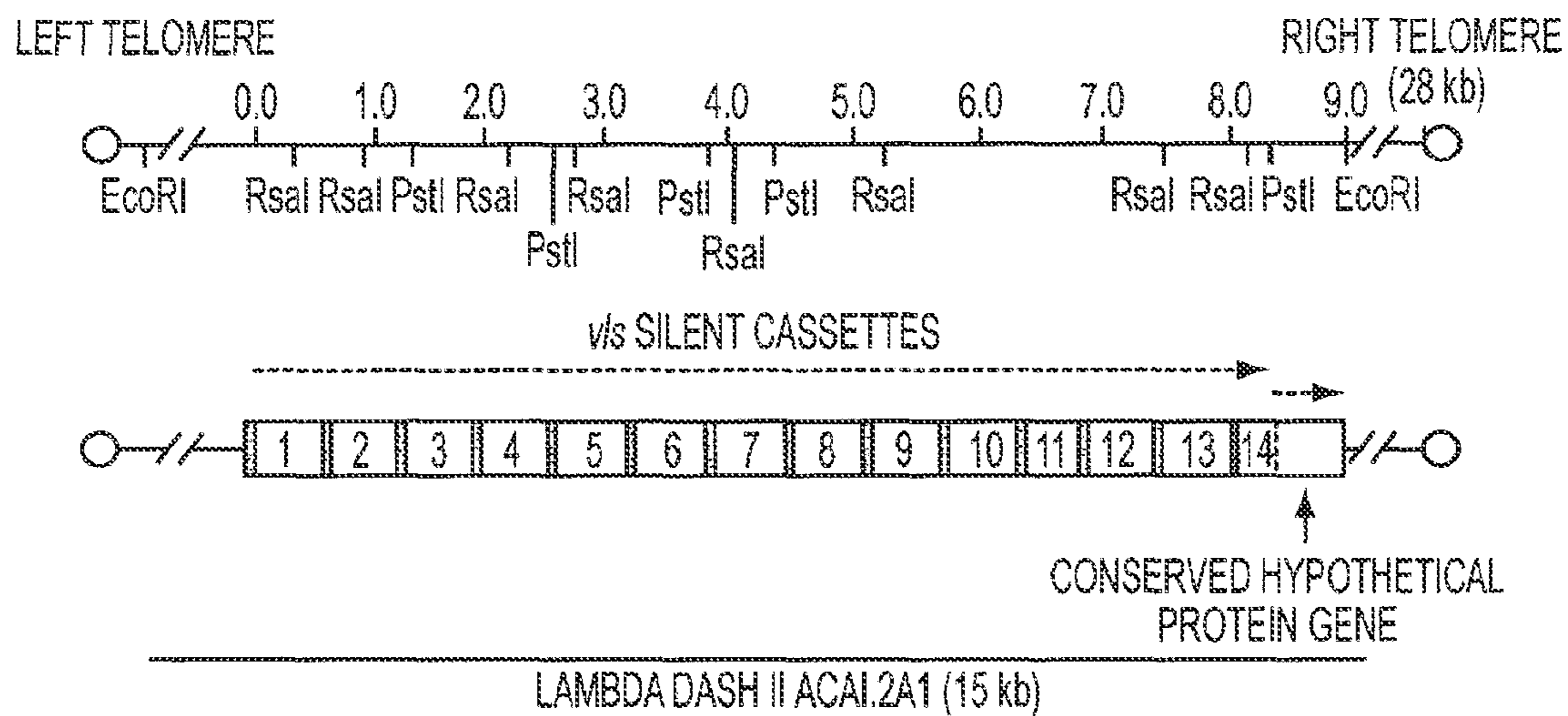


FIG. 1B

	VR-I	VR-II	VR-III
cassette1	ESAVIGVSKWLEEMIAAKKAAFK---GGTGGSEXIGVGAANNQGVADKDSVKGIAKGIKGIIVDAGKAFKDG	---NALTGVKVEADEA---CA-NELIACKLIFACVAGNA	---AAD---
cassette2	...GG...-...NN...-SD...K...AS...E...	---KD,AK...D,A...-AN	...ACG...DADDAN
cassette3	...T...G...G--DA...AD...E...	---KD,A...D---KKE	...G,VAD...A---
cassette4	...T...DG,A...N...A,D,N...EN...E...	KDGD,KD,ET,A,N--E...K...	AN...G...VGD---
cassette5	...T...-NN...SD,-N,K,AS,N...N...E...	---S,KD,T,A,N--E...K...	KN...D...AAD---
cassette6	K...E...G...G--DA...AD...A--DK...AS...E...	E...S,KD,T,A,N--E...K...	...G...D...D---
cassette7	K...GE...G...KV---V,A...AD...D,K...K,ES,N...E...	---A,AAA,-N--DD-KK...	KN,S,G...A---
cassette8	...T...G...-...V,A...AD...D,K...K,ES,N...E...	E...S,KD,AK,D---D...K...	...GG...G---
cassette9	...GE...A...GGT...SD...N...AS...E...	---KD,A...DE---A...	EN...GCAAD---
cassette10	...E...S...KV---A,DD...S...-...AG...	E...D,KD,AK,N--D...K...	EN...G...A---
cassette11	...I...T...T...DA,A,V--DA...AD...K,K,K,AS...E...	---A,AK,DE---A...	AN,GANA,ADD---
cassette12	...E...T...G...-...EA...DANK	---D,KD,AG,D---KE	QD,GG...GD---
cassette13	K...EA...T...G...-...EA...DANK	---AL,D,AA,GDE...K...	...K,A...HGDSEA---
cassette14	K...E...T...S...D...-...EA...DANK	---KL,A,AAK--EN,KG	...
R31 VLSE1	G...IKE...EL...DKIV...V...-A...-E,ASS,TAA...E,V,DADA...A...	...E...E...-SE	...

	VR-IV	VR-V	VR-VI
cassette1	IAKAGAVTAVSGETILKAIVD--GAGGAA-QGCKKAA-EAKMPIAAALIGADAAG--ADFG-DMKK-SDMIAAIVIRGVAKSGKTFANAA--KRESVKSAV	TNDD,--E,K-G...-N	NDS,A...
cassette2	...A,A,N...-D...	...AG...-N...RN...V	A,ANDNS,A...
cassette3	...A...D-A...D-A...	N,DNA,A,K,E...-	NDD,A...
cassette4	...A,D,D-A...-...	TNE...-E,-RN	...ADN,-AS
cassette5	...D,N,A...-...	AD,AA,A,NEN...-	A,D,D--ANN,-AS
cassette6	...A,DK,N...-D...	TADD...E,K-	DD-N,A...
cassette7	...A,A,N,A...-D...	...CA--EEFK,E...-	-N--DAAN
cassette8	...A,A,D-A,AA-G-A...	TNE...A,K-G...RN,N	AAD-AG,AR,*RVL
cassette9	...A,A,D-A,A,D-A...	T,D...A,Q...RN,N	NDS,A...
cassette10	...A...D,N,A...D-	AGD...K,E,RN	A,AND--S,A...
cassette11	...A...-V,AG,G-A,I	T,D,A-E,EN...N,N	ANANDAG
cassette12	...A,A,D-A,V...E-	T,DDNAA,FDK-E...SN	ANADNN-S,A...
cassette13	...A...DK,N,V,V...GA,I	GAG...A,EN...RN,N	KEDY*
cassette14	...T...A,DA,E...PE-	DKDG...E,Q,E...-D,Q	...KD-G--E,K
R31 VLSE1	AS...	...A...M...D...	...

FIG. 2A

			VR - I		VR - II	VR - III
cassette10	KGTV ----KNAVDMTKAAVAASA ----ASAATGNAAIGDVVNGDG -AAKGGDAASVNGTAKGKIGVDAAEKADAREKLEIVACAGAGAEAGNEAGKLFVKKNAGDHGGEAGDAG					
cassette11	E,AITEIS.WLD,A,A.... --E. ----G. ~			D...D., -GAGGG...A----	....GA., I~~~~
cassette12	E,AITEIS.WLD,A,A.... ----			D...D., ~ .....	....E....N...
cassette13	E.....A,A,E.....STT...KS--GE..D.....			D.....-TT.VWV.....	N., -NE.,D.,S....	
cassette14				.....	.....
cassette15	E... ----A,A..... --E. ----K.S.G.A.....			D.....-T.XD.....	....D.,D.,....
cassette16	.... ----A,A,EE..... --E. ----KNSGA-.....E.....			DAT..E., -TT.VN.....	RA.,D.,G.,DADDEAGK
cassette17	.....I.,E..... --E. ----S.....DVA-K.....			A.,E., -TT.AD.....	....-..NV.....
cassette18	.... ----I.,E..... --E. ----S.....GAT.....K.....			D.,D., -T.KD.....	N., -NE.,D.,L.,...
cassette19	E.....GSAFNKT,V,I,NLVRKTVOA,LRKV.....KNSG---D.....			D.....-T.KD.....	....-NE....N.....
cassette11	.... --I.,T..... --E. ----S.....			.....	.....
B31 V1SE1	E,AI ---KEVSEILD,IVKAVKT, ---EG,SS,T.....E.,ADA, --,VA,K.,K.....E.,E.,GGSE ---,KAVA,KG,N,KG.....G,AG,AA, -,DSEA,S			.....	.....

			VR - IV	VR - V	VR - VI
cassette10	RAAAVAVSGEQILKAIIVDAKDGGDKQG-KKAEDAEHPIDAALIGSTGADNNAEAF --ATMKKDDQIAAMVIRGMKDGQFALK ---DAAHDNH				
cassette11	K.....E,D..... --A.,T.....E.....GAD,GA, --, --NK			....D.,AAH~
cassette12	K.....VTDVK.,T.....E..... --TN.,D.A., --,			....D....K,~
cassette13	.....T.,V,A..... --,AD., -,NKFG			TNNA.....
cassette14	K.....T.VTDVK.,T..... --,SA,AN., --,DK			....-NND....
cassette15	.....VA.....			.....
cassette16	K.....E..... --A.,T.....S,N-,ND.,A., --,			....-,,AAH~
cassette17	K.....T,KNNVK.....E.....SADA,A.,FNK --,EC			FNDA.....	
cassette18	K.....D..... --,T.....GA.,GA.,A., --,NV			T --NN.,T.,	
cassette19	.....			.....
B31 V1SE1	K.,G.,S.....S.,T., -AAEQD, -,P.,E.,K.,A.....D--K.GG,HFGQ--DH			.....IA.....K.,V, --,GEKKA

FIG. 2B

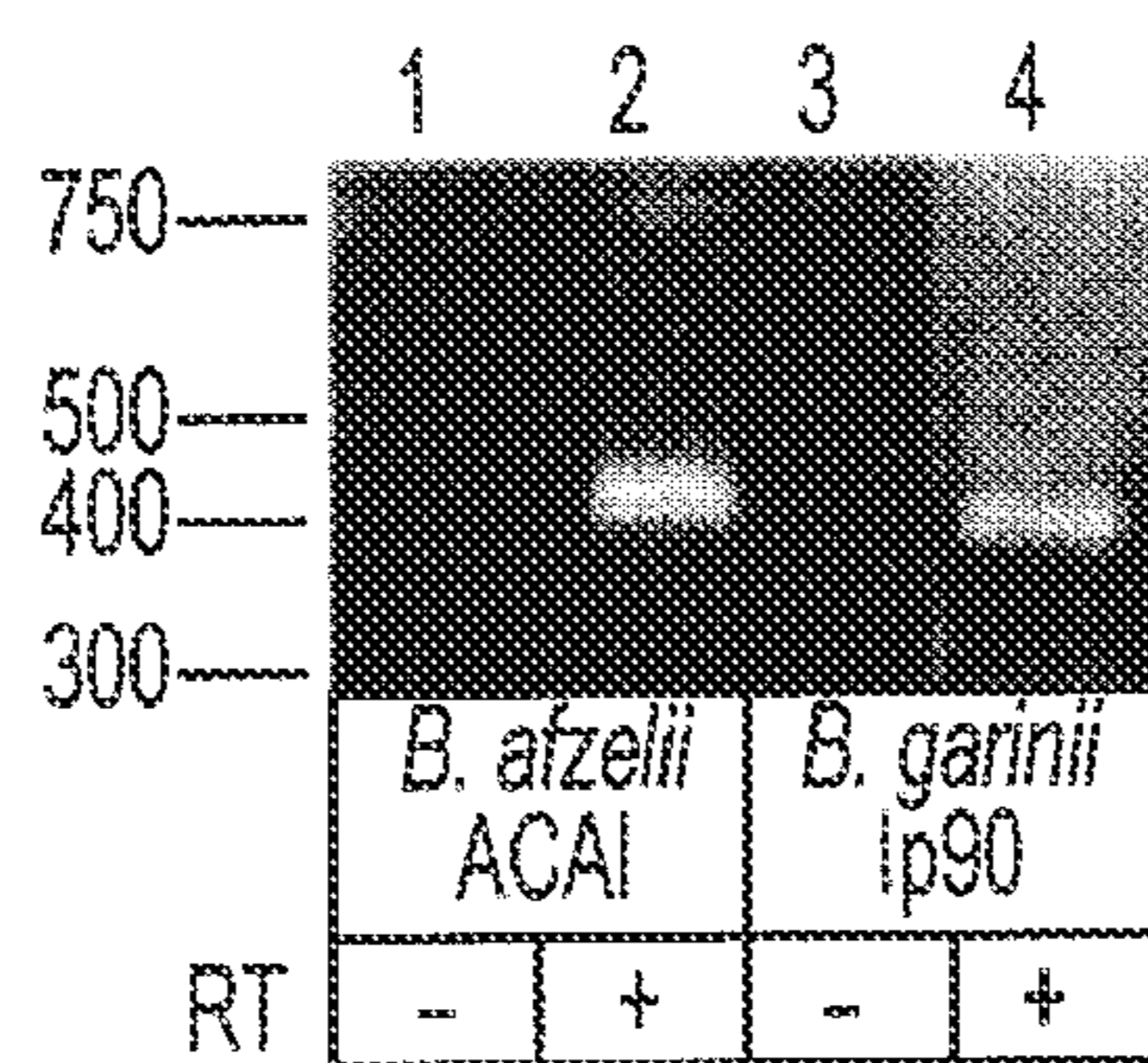


FIG. 3

VR-II VR-III

ACAI VISE Clone 2622 1 GIVAAAGKAFGKDGDAITGVAKAA-ENIANKDAGKLFAGKNGNAGAA--DIAKAAAAVTAVSGEQILKAIY

vis8 vis7

ACAI VISE Clone 2624a 1 ...D...[E.S..KD...V.ODD...].G...[...G...DA...].G.....

vis10 vis12

ACAI VISE Clone 2624b 1 ...D...[E...KD...V.D..GD...].E...[...G.ADA...].E.....

vis6 vis5

ACAI VISE Clone 2625 1 ...E...[E.S..KD.KIV.A..E...].E...[...D..DAA...].G..S.....

VR-IV VR-V

ACAI VISE Clone 2622 69 EAAGDA-DQAGVKADAANKPIIAAATGTADDGAAFGKDEMKRNDKIVAAIVLRGV

vis7

ACAI VISE Clone 2624a 69 [D...A..AN...K..AD...].E...[...EF..D...S.N.A...].E.....

vis12

ACAI VISE Clone 2624b 73 [....A.....EE...].E...[...D.A...EFGENDM.K.N.A...].E.....

vis5

ACAI VISE Clone 2625 72 [DG...AN...K..AE...].E...[...NEA...EFG.D...].A.....

FIG. 4A

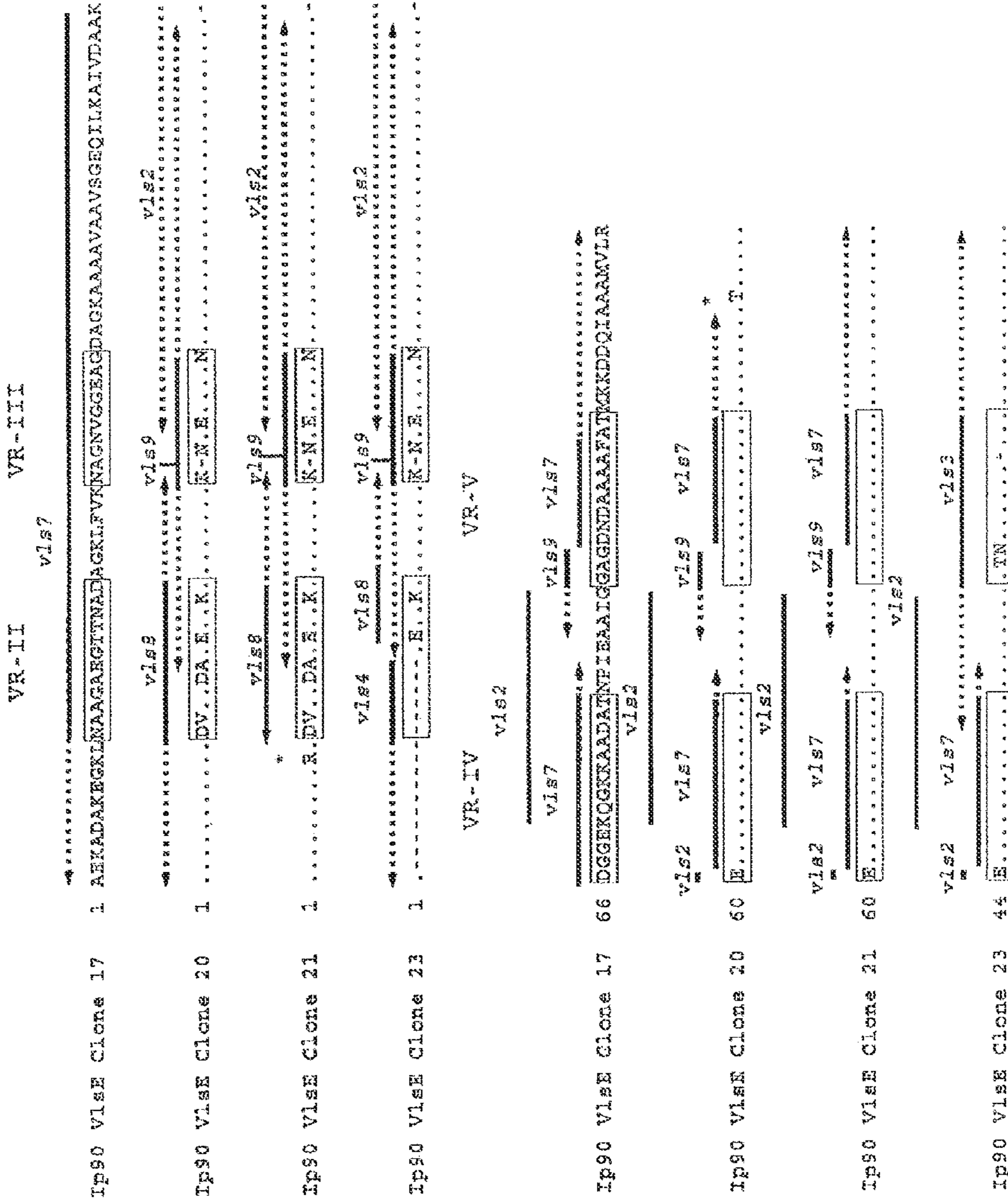


FIG. 4B

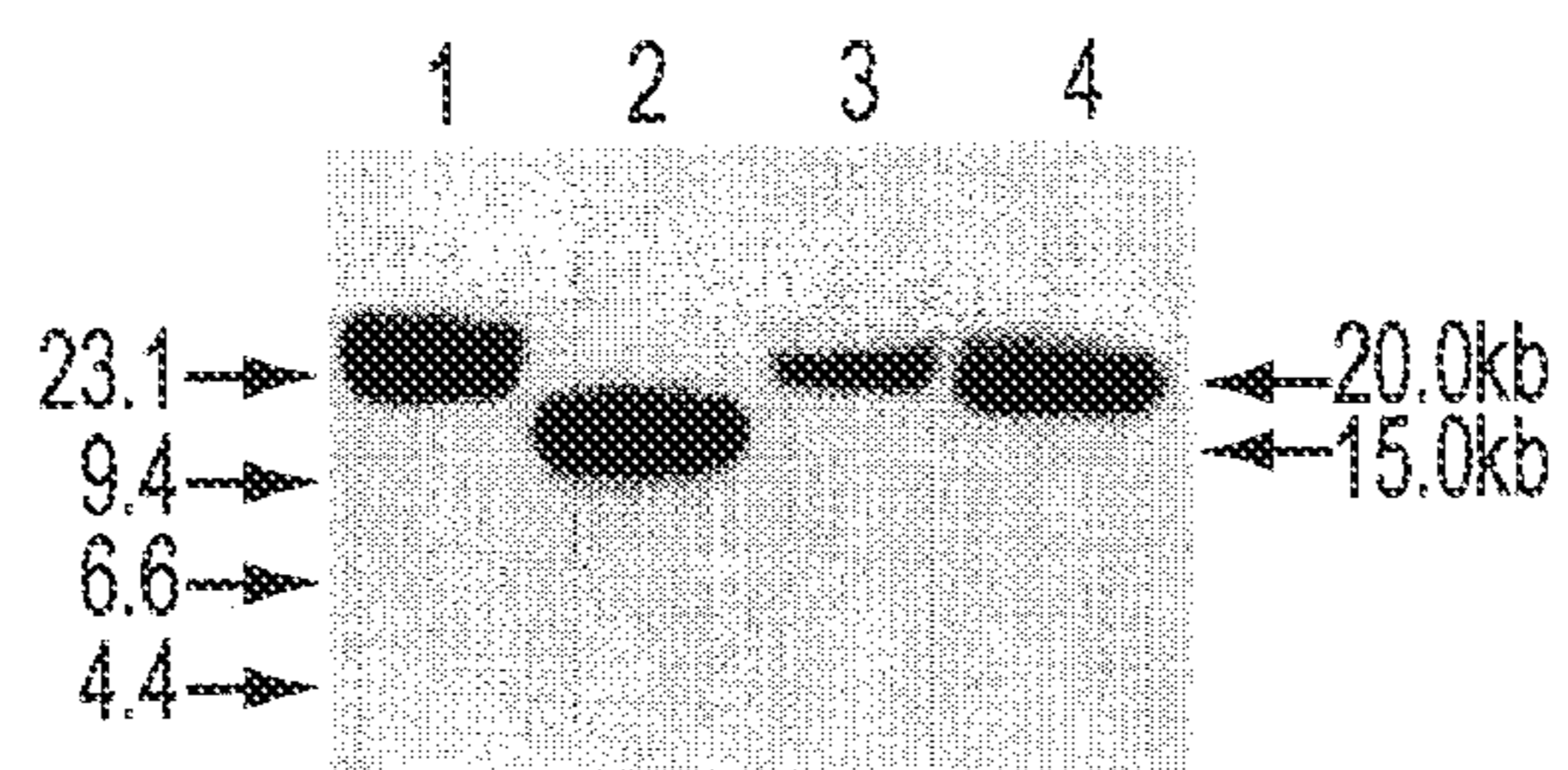


FIG. 5

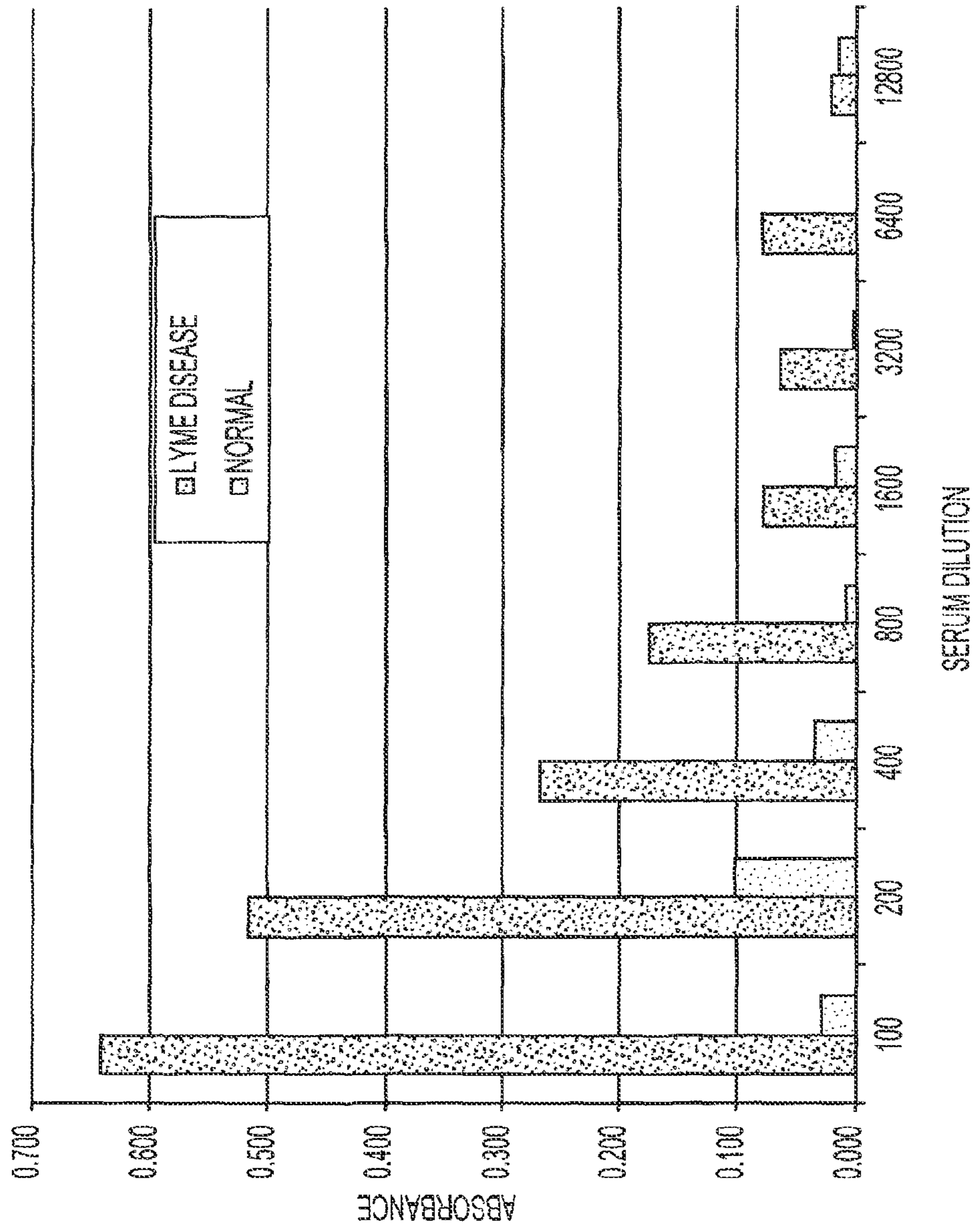


FIG. 6

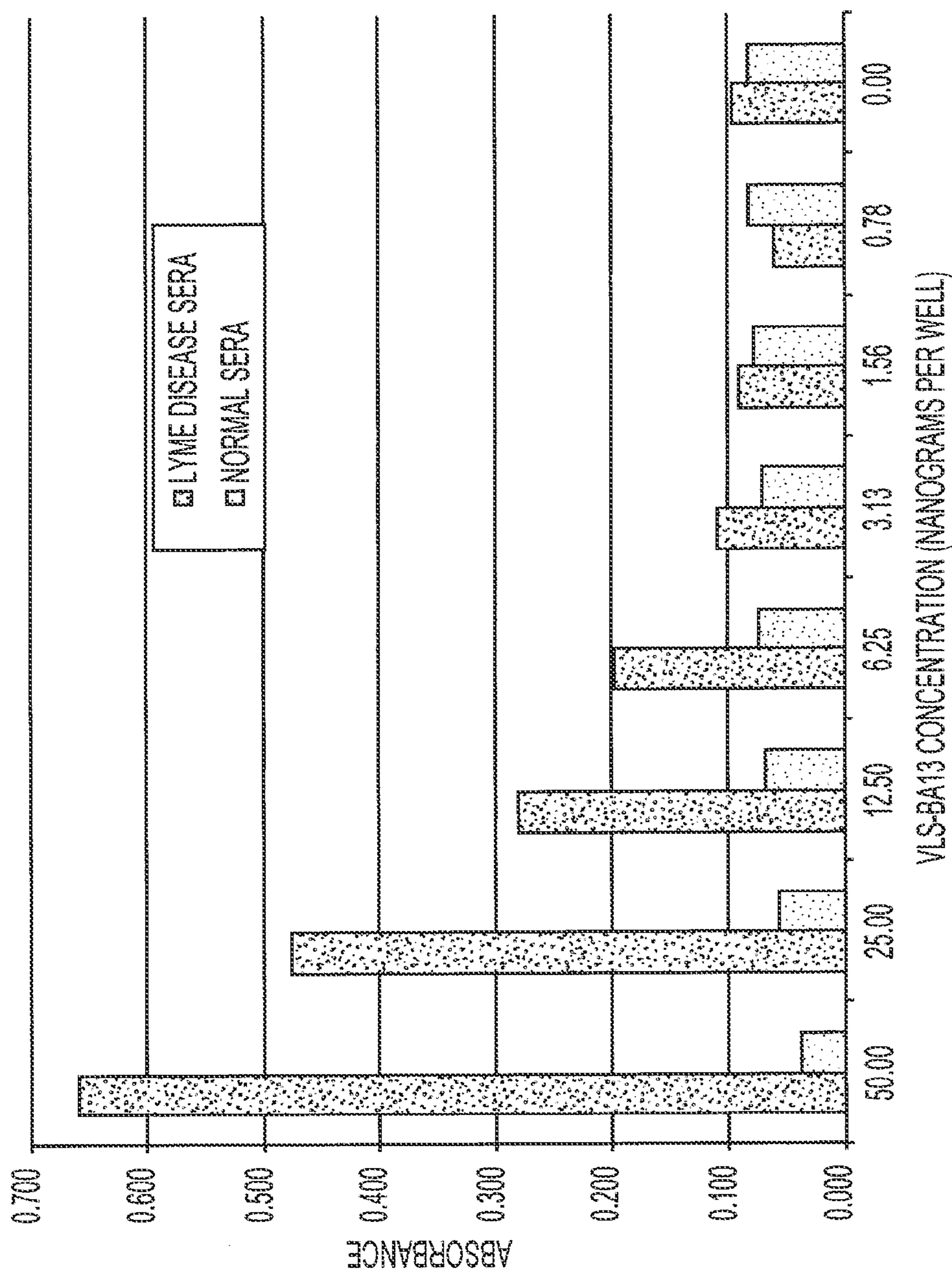


FIG. 7

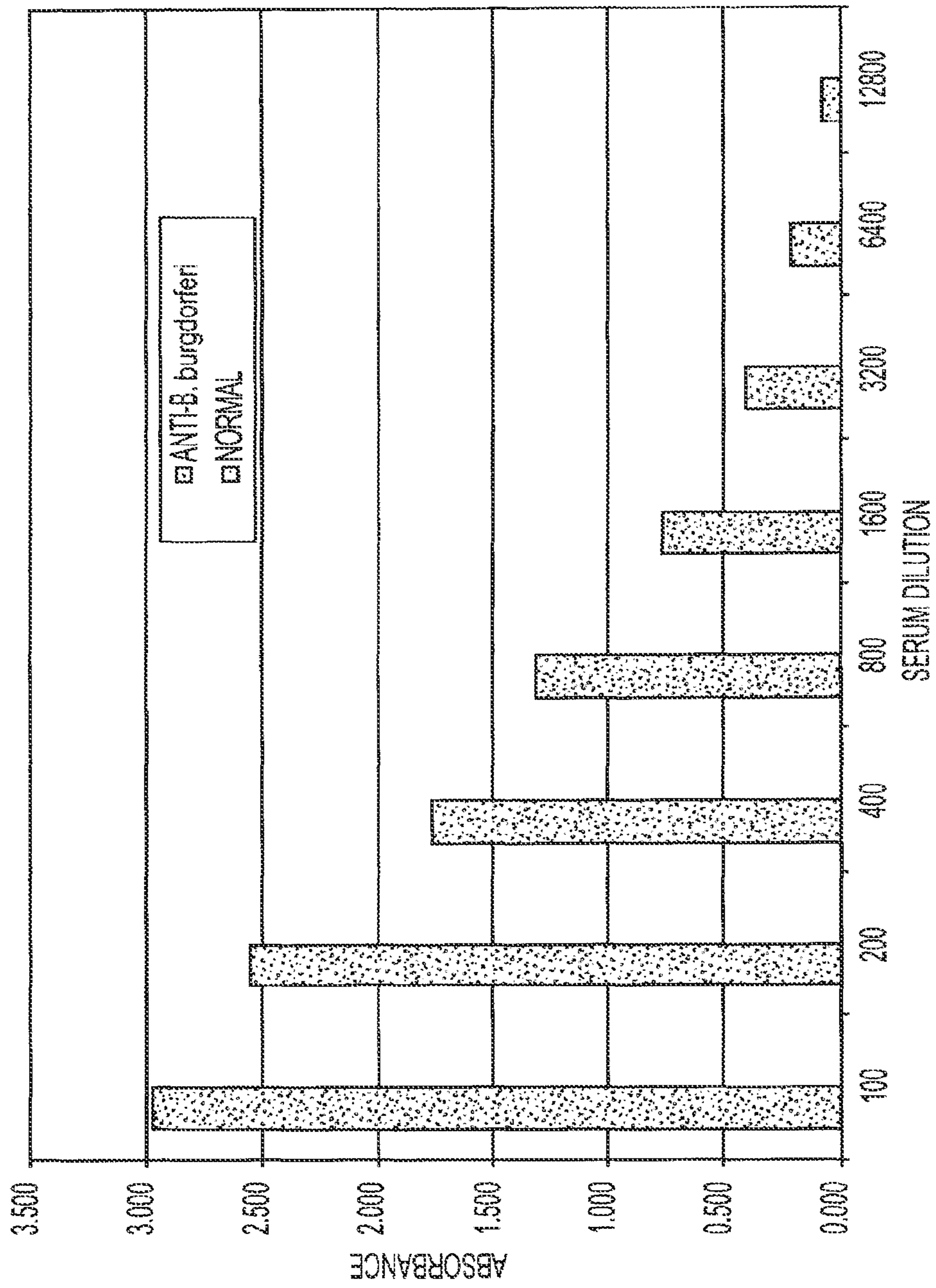


FIG. 8

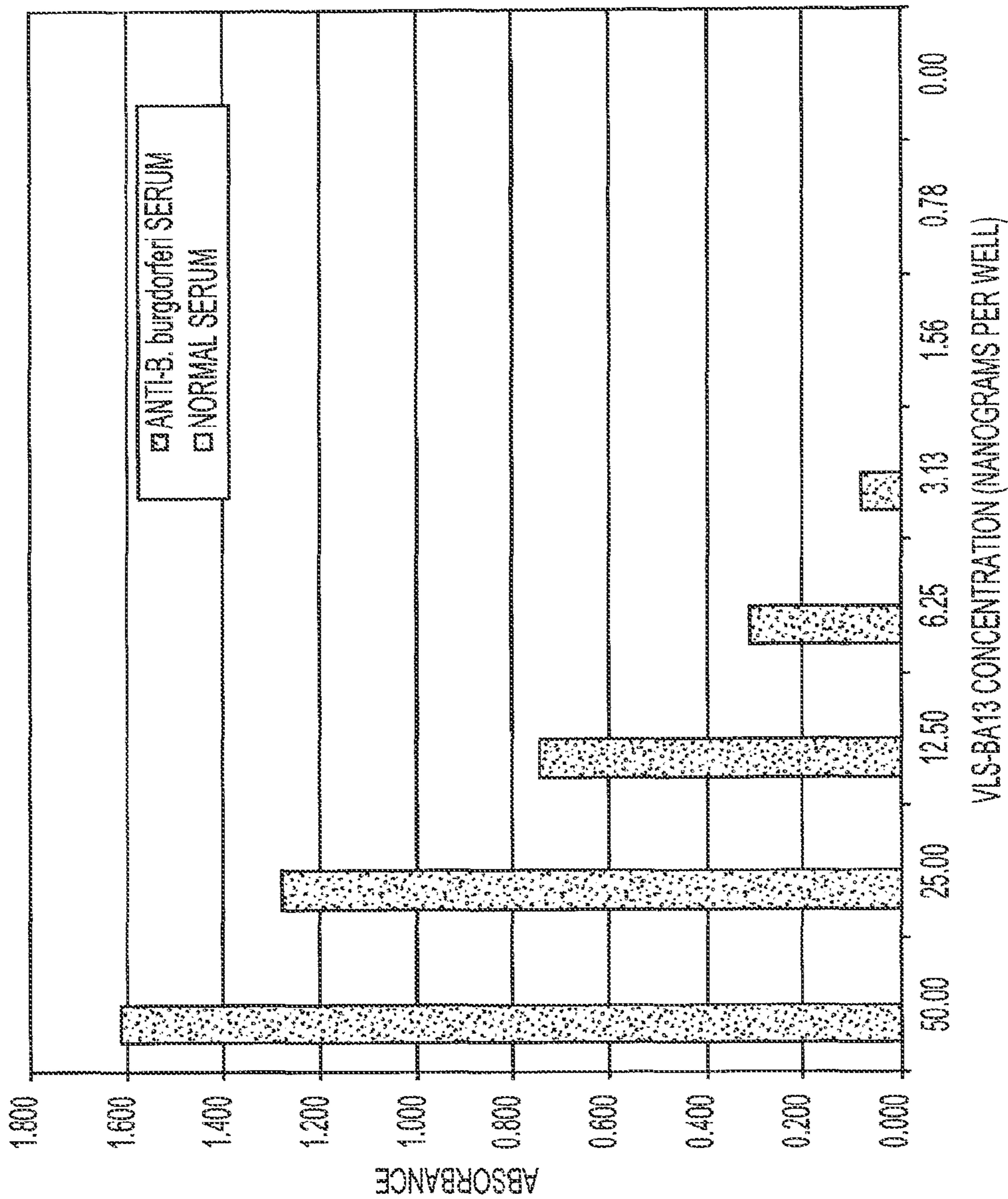


FIG. 9

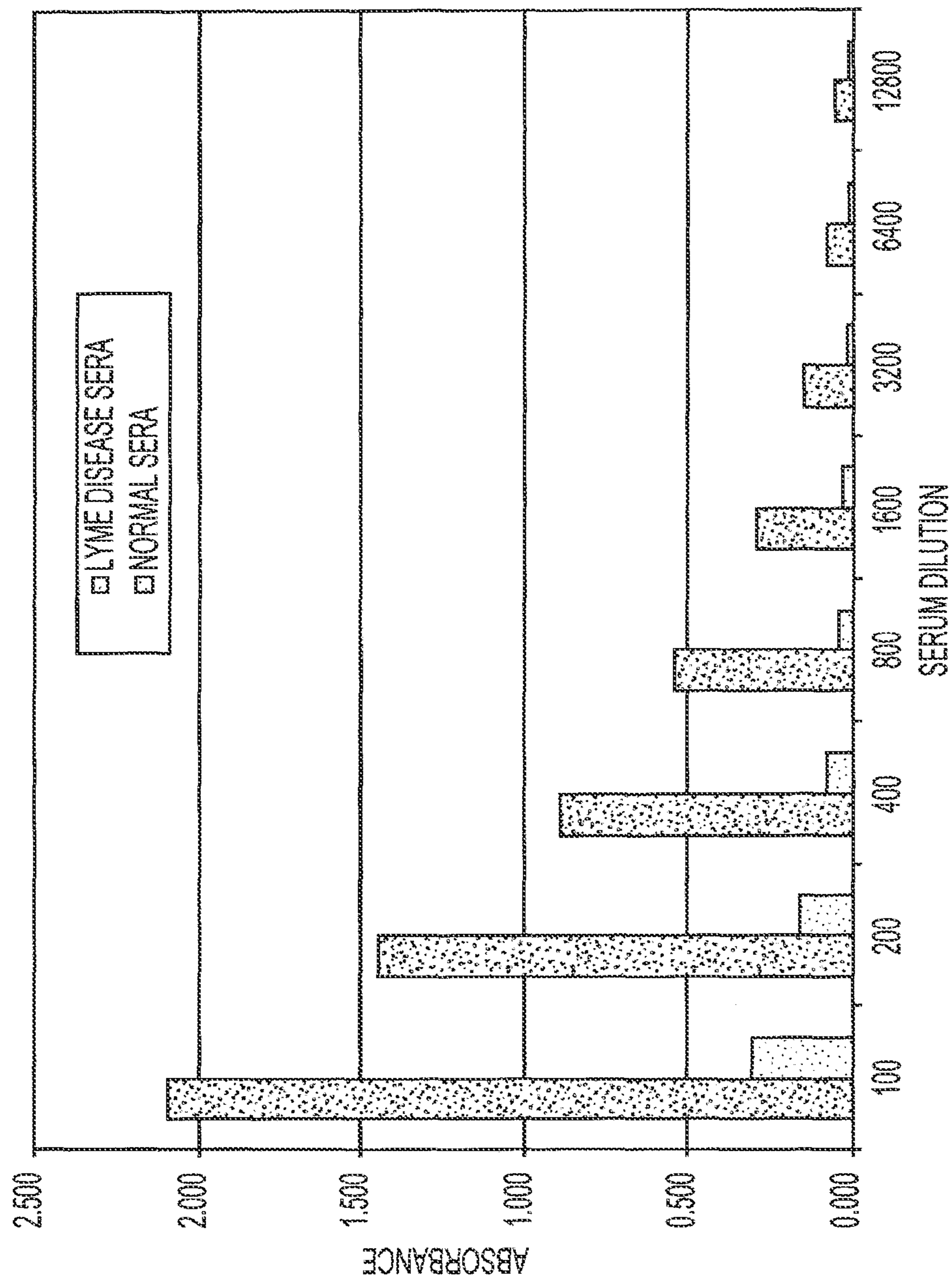


FIG. 10

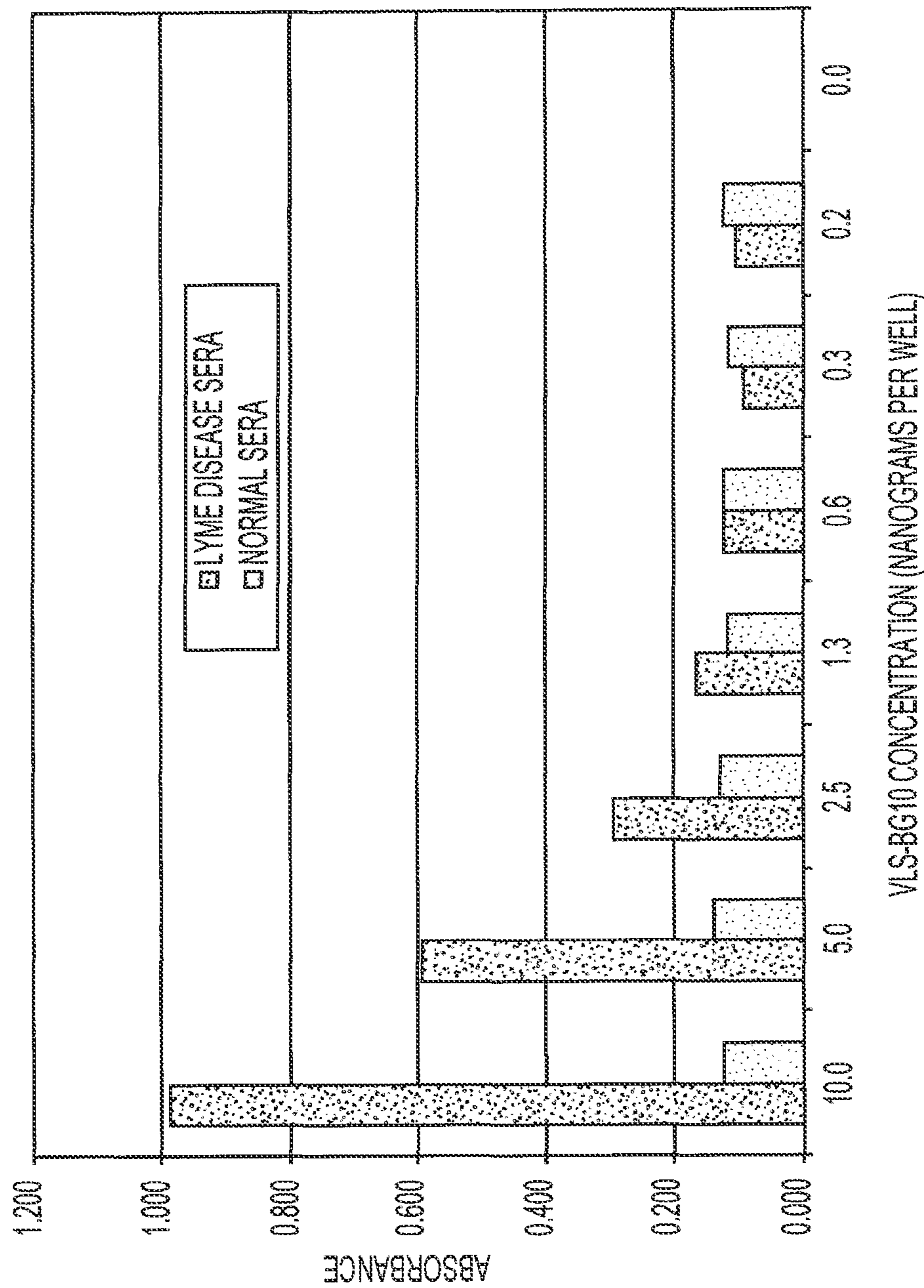


FIG. 11

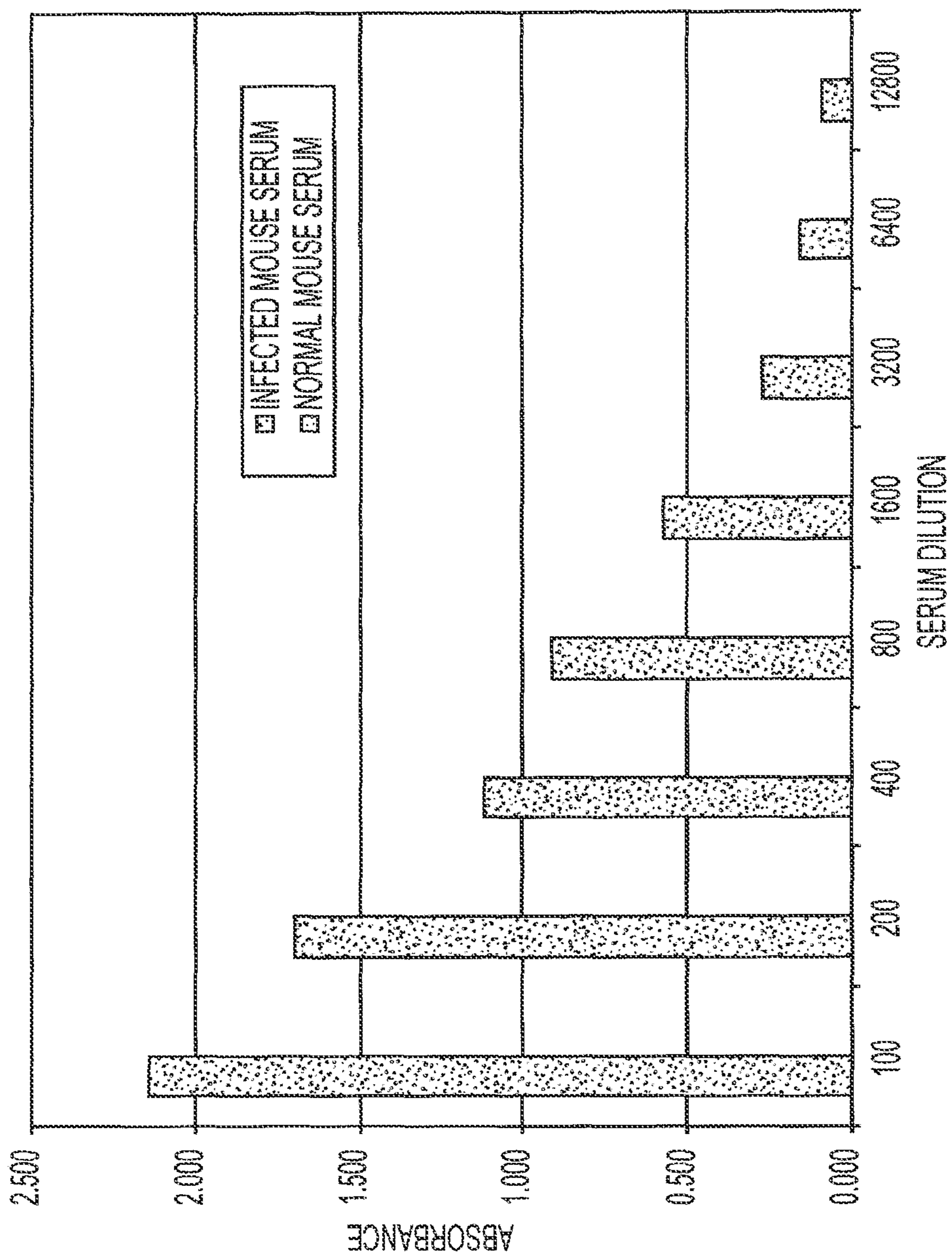


FIG. 12

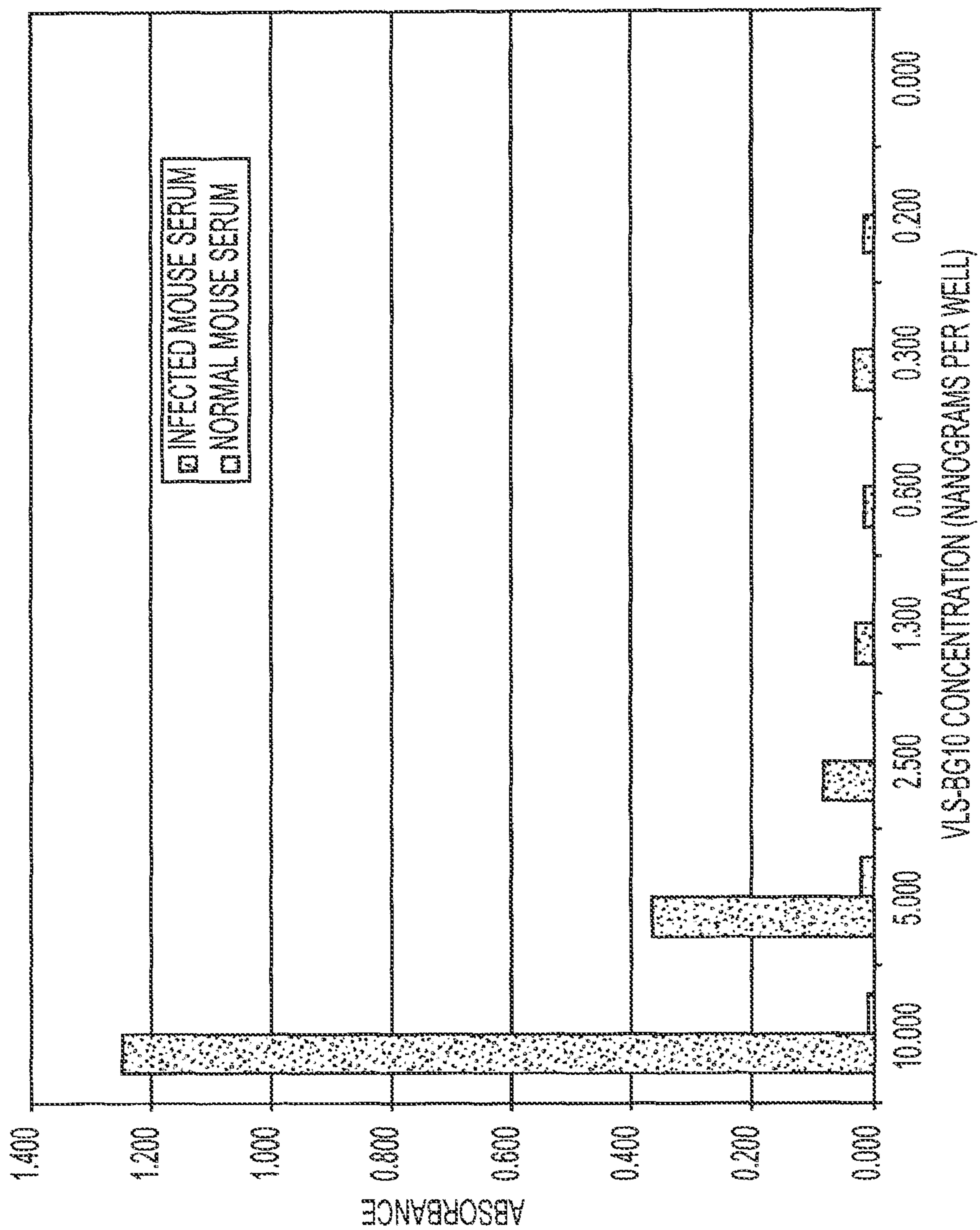


FIG. 13

**VMP-LIKE SEQUENCES OF PATHOGENIC
BORRELIA SPECIES AND STRAINS**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/257,613, filed Apr. 21, 2014, now U.S. Pat. No. 9,115,193, which is a continuation of U.S. patent application Ser. No. 13/645,950, filed Oct. 5, 2012, now U.S. Pat. No. 8,722,871, issued May 13, 2014, which is a divisional of U.S. patent application Ser. No. 13/324,357, filed Dec. 13, 2011, now U.S. Pat. No. 8,283,458, issued Oct. 9, 2012, which is a divisional of U.S. patent application Ser. No. 12/962,154, filed Dec. 7, 2010, now U.S. Pat. No. 8,076,470, issued Dec. 13, 2011, which is a divisional of U.S. patent application Ser. No. 10/539,956, filed on Apr. 6, 2006, now U.S. Pat. No. 7,847,084, issued on Dec. 7, 2010, which is a U.S. national phase application under 35 U.S.C. §371 of International Application No. PCT/US03/041182, filed Dec. 22, 2003, which claims priority to U.S. Provisional Patent Application No. 60/435,077, filed Dec. 20, 2002. The entire text of each of the above-referenced disclosures is specifically incorporated by reference.

This invention was made with government support under AI37277 awarded by the National Institutes of Health. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

A. Field of the Invention

The invention relates to the field of molecular biology; in particular, to immunogenic compositions and recombinant VMP-like genes useful for treatment and diagnosis of Lyme disease. Also included are methods for the determination of virulence factors in Lyme disease.

B. Description of Related Art

Lyme disease is a bacterial infection caused by pathogenic spirochetes of the genus *Borrelia*. The infection can occur in humans, dogs, deer, mice and other animals, and is transmitted by arthropod vectors, most notably ticks of the genus *Ixodes*. *Borrelia burgdorferi*, the most common cause of Lyme disease in North America, was first cultured in 1982. *B. garinii* and *B. afzelii* are the most common infectious agents of Lyme disease in Europe, and another species, *B. japonicum*, has been described in Japan. These organisms are closely related and cause similar manifestations with multiple stages: an expanding rash at the site of the tick bite (erythema migrans); fever, lymphadenopathy, fatigue, and malaise; effects of disseminated infection, including carditis, meningoradiculitis, and polyarthritis; and chronic manifestations including arthritis and neurologic disorders.

Lyme disease is often difficult to diagnose because of shared manifestations with other disorders, and it can also be refractory to treatment during late stages of the disease. It is most common in areas such as suburban regions of upstate New York and Connecticut, where large populations of deer and white-footed mice serve as the principal mammalian hosts and reservoirs of infection. Approximately 20,000 cases of Lyme disease in humans are reported per year in the United States, and it is also a significant veterinary problem due to a high infection rate of dogs and other domestic animals in endemic regions.

The pathogenic *Borrelia* that cause Lyme disease are able to persist for years in patients or animals despite the presence of an active immune response. Antigenic variation is a mechanism by which members of the genus *Borrelia* may be

able to evade the host immune response (Zhang, 1997). Antigenic variation has been defined as changes in the structure or expression of antigenic proteins that occurs during infection at a frequency greater than the usual mutation rate (Borst and Geaves, 1987; Robertson and Meyer, 1992; Seifert and So, 1988).

Relapsing fever is another disease caused by pathogenic *Borrelia*. It has both epidemic and endemic forms. The epidemic form is caused by *B. recurrentis* and is transmitted between humans by lice. It was a major source of morbidity and mortality during World War I, but has been rare since then due largely to public health measures. Endemic relapsing fever is an epizootic infection caused by several *Borrelia* species, including *B. hermsii*. It occurs sporadically among hunters, spelunkers, and others who come in contact with infected soft-bodied ticks of the genus *Ornithodoros*. Relapsing fever is characterized by two or more episodes or “relapses” of high bacteremia (up to 10^8 /ml). The first wave of infection is caused by *Borreliae* expressing a certain Variable Major Protein (VMP) on their surface (e.g. Vmp21). The gene encoding this VMP is located at a promoter site in the expression plasmid, whereas over 24 nonexpressed copies of different VMP genes are present on the so-called silent plasmid. When the host develops antibodies against the expressed VMP, the organisms of that serotype are destroyed and the patient improves. However, a small proportion of organisms have undergone antigenic switching to a different serotype. Nonreciprocal recombination occurs between the expression plasmid and the silent plasmid, resulting in the insertion of a different VMP gene in the expression site (e.g., Vmp7). The organisms expressing Vmp7 are not affected by the anti-Vmp21 antibodies, and therefore multiply in the host and cause a second episode of the disease. Up to five of these 3-5 day episodes can occur, separated by 1-2 week intervals.

Such well-demarcated episodes of infection do not occur during Lyme disease, and fewer organisms are present in the blood at any stage. However, there are reasons to suspect that similar mechanisms of antigenic variation may occur in *B. afzelii* and other Lyme disease *Borreliae* such as *B. garinii* and *B. burgdorferi*. The infection, if untreated, commonly persists for months to years despite the occurrence of host antibody and cellular responses; this observation indicates effective evasion of the immune response. Lyme disease may be disabling (particularly in its chronic form), and thus there is a need for effective therapeutic and prophylactic treatment.

Genetic loci analogous to the VMP antigenic variation system have been detected in North American and European Lyme disease *Borrelia* by Southern hybridization and PCR analysis (Wang et al., 2001). In addition, sequences from fragments of vls (VMP-like sequence) silent cassettes have been reported for the *Borrelia burgdorferi* strains 297 and N40, and the *Borrelia garinii* strains Ip90 and A87S (Liang and Philipp, 1999; Wang et al., 2001), (S. Feng and S. W. Barthold, unpublished data). VMP-like sequences of *B. burgdorferi* have been described and patented in U.S. Pat. No. 6,437,116.

Open reading frames in a *B. burgdorferi* plasmid that encode hypothetical proteins resembling the VMP proteins of relapsing fever organisms have been identified (Zhang et al., 1997). The inventors have found that the presence of the plasmid containing these VMP-like sequences in *B. burgdorferi* clones correlates strongly with infectivity (Zhang et al., 1997; Purser and Norris, 2000). Thus it is likely that the proteins encoded by the VMP-like sequences are important in immunoprotection and pathogenesis. Proteins encoded by

the VMP-like sequences of *B. burgdorferi* may provide protection when used either alone or in combination with other antigens. They may also be useful for immunodiagnosis.

Greater than 90% of Lyme disease patients beyond the erythema migrans stage from North America and Europe express antibodies against VlsE (Liang et al., 1999; Liang et al., 2000). In addition, mice infected experimentally with *Borrelia afzelii* and *Borrelia garinii* strains express anti-VlsE antibodies (Liang et al., 2000). Finally, a protein product of ~35 kDa expressed by *Borrelia garinii* Ip90 reacts with antibodies against IR6, a peptide corresponding to invariant region 6 of the VlsE cassette region (Liang et al., 1999a). Portions of several vls silent cassettes from *Borrelia garinii* strain A87S have been published (Wang et al., 2001). Further, several amino acid sequences of *Borrelia garinii* Ip90 have been previously characterized by Liang et al. (1999a).

There is a commercial demand for vaccines and diagnostic kits for Lyme disease, both for human and veterinary use. Several companies have active research and development programs in these areas.

SUMMARY OF THE INVENTION

Partial and complete DNA sequences have been determined for several recombinant clones containing DNA encoding VMP-like sequences. The identification and characterization of these sequences now allows: (1) identification of the expressed gene(s) or DNA segments containing open reading frames in several *Borreliae*; (2) expression of these gene(s) by a recombinant vector in a host organism such as *E. coli*; (3) immunization of laboratory animals with the resulting polypeptide, and determination of protective activity against *Borreliae* infection; (4) use of antibodies against the expressed protein to identify the reactive polypeptide(s) in *Borreliae* cells; (5) use of the expressed protein(s) to detect antibody responses in infected humans and animals; (6) determination of the presence, sequence differences, and expression of the VMP-like DNA sequences in other Lyme disease *Borreliae*.

The invention is contemplated to be useful in the immunoprophylaxis, diagnosis, or treatment of Lyme disease, relapsing fever, or related diseases in humans or animals. It is expected that recombinant or native proteins expressed by the VMP-like genes (or portions thereof) will be useful for (a) immunoprophylaxis against Lyme disease, relapsing fever, or related disorders in humans and animals; (b) immunotherapy of existing Lyme disease, relapsing fever, or related illnesses, by way of immunization or injection of antibodies directed against VMP-like proteins; and (c) immunodiagnosis of Lyme disease, relapsing fever, or related diseases, including their use in kits in which the VMP-like proteins are the sole antigen or one of multiple antigens. The DNA may be employed in: (a) production of recombinant DNA plasmids or other vectors capable of expressing recombinant polypeptides; and (b) design and implementation of nucleic acid probes or oligonucleotides for detection and/or amplification of VMP-like sequences. The latter is expected to have application in the diagnosis of infection with *Borrelia* organisms.

Another aspect of the invention is the method for identification of possible virulence factors. This approach entails subtractive hybridization of target DNA from high infectivity organisms with driver DNA from low-infectivity strains or clones. This procedure greatly enriches for sequences which differ between the high- and low-infectivity strains

and thus may encode proteins important in virulence. Of particular utility is the use of closely related isogenic clones that differ in their infectivity; in this case, the DNA differences should be restricted more stringently to those related to infectivity.

The invention is considered to include DNA segments corresponding to 10, 20, 30, and 40 base pairs of the VMP-like sequences; DNA segments inclusive of the entire open reading frames of the VMP-like sequences; shorter DNA segments containing portions of these open reading frames; amino acid sequences corresponding to both conserved and variable regions of the VMP-like sequences; recombinant vectors encoding an antigenic protein corresponding to the above amino acid sequences; recombinant cells where extrachromosomal DNA expresses a polypeptide encoded by the DNA encoding *Borrelia* VMP-like sequences; a recombinant *Borreliae* or *E. coli* cell containing the DNA encoding VMP-like sequences; methods of preparing transformed bacterial host cells using the DNA encoding the VMP-like polypeptides; methods using the plasmid or another vector to transform the bacterial host cell to express *Borreliae* polypeptides encoded by the DNA sequences; and methods for immunization of humans or animals with the native *Borreliae* polypeptides, polypeptides expressed by recombinant cells that include DNA encoding the VMP-like polypeptides, or synthetic peptides that include VMP-like sequences.

Also included in the invention are primer sets capable of priming amplification of the VMP-like DNA sequences; kits for the detection of *Borreliae* nucleic acids in a sample, the kits containing a nucleic acid probe specific for the VMP-like sequences, together with a means for detecting a specific hybridization with the probe; kits for detection of antibodies against the VMP-like sequences of *Borreliae* and kits containing a native, recombinant, or synthetic VMP-like polypeptide, together with means for detecting a specific binding of antibodies to the antigen.

A preferred embodiment of the present invention is an isolated nucleic acid comprising a nucleotide sequence that encodes an antigenic peptide of *Borrelia garinii* or *B. afzelii*. More preferably, the present invention provides an isolated nucleic acid that encodes at least 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 75, 100, 125, 150, 175, 200 or more contiguous amino acids of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97. Further, the invention contemplates any range derivable between any of the above-described integers.

In another embodiment, the present invention provides an isolated nucleic acid comprising 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109,

110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 125, 150, 175, 200, 300, 400, 500 or more contiguous nucleotides of SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, and SEQ ID NO:96. Further, the invention contemplates any range derivable between any of the above-described integers.

In yet another embodiment, the isolated nucleic acid comprises a complement to or a degenerate variant of 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 125, 150, 175, 200, 300, 400, 500 or more contiguous nucleotides of SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, and SEQ ID NO:96. Further, the invention contemplates any range derivable between any of the above-described integers.

In some embodiments the isolated nucleic acid is a DNA molecule. In other embodiments the isolated nucleic acid is an RNA molecule.

In certain embodiments the invention provides an isolated nucleic acid obtained by amplification from a template nucleic acid using a primer selected from the group consisting of SEQ ID NO:21, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:26, SEQ ID NO:27, SEQ ID NO:98, SEQ ID NO:99, SEQ ID NO:100, SEQ ID NO:101, SEQ ID NO:102, SEQ ID NO:103, SEQ ID NO:104, SEQ ID NO:105, SEQ ID NO:106, and SEQ ID NO:107.

The nucleic acid segments of the present invention, regardless of the length of the coding sequence itself, may be combined with other DNA sequences, such as promoters, enhancers, polyadenylation signals, additional restriction enzyme sites, multiple cloning sites, other coding segments, and the like.

A preferred embodiment of the present invention is an isolated polypeptide comprising 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 75, 100, 125, 150, 175, 200 or more contiguous amino acids of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:24, SEQ ID NO:26, SEQ ID NO:28, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:88, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, SEQ ID NO:96, and SEQ ID NO:98.

NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97. Further, the invention contemplates any range derivable between any of the above-described integers.

In one aspect, the present invention provides for an isolated polypeptide or an isolated nucleic acid encoding a polypeptide having between about 70% and about 75%; or more preferably between about 75% and about 80%; or more preferably between about 80% and 90%; or even more preferably between about 90% and about 99% of amino acids that are identical to the amino acids of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97 or fragments thereof. The percent identity or homology is determined with regard to the length of the relevant amino acid sequence. Therefore, if a polypeptide of the present invention is comprised within a larger polypeptide, the percent homology is determined with regard only to the portion of the polypeptide that corresponds to the polypeptide of the present invention and not the percent homology of the entirety of the larger polypeptide.

In addition, the present invention encompasses fragments of polypeptides or nucleic acids encoding fragments of polypeptides that have between about 70% and about 75%; or more preferably between about 75% and about 80%; or more preferably between about 80% and 90%; or even more preferably between about 90% and about 99% of amino acids that are identical to the amino acids of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97 even if the particular fragment itself does not have between about 70% and about 75%; or more preferably between about 75% and about 80%; or more preferably between about 80% and 90%; or even more preferably between about 90% and about 99% amino acid homology with the polypeptides of the present invention.

In another embodiment the invention provides an isolated polypeptide that binds immunologically with antibodies raised against an antigenic polypeptide of *Borrelia garinii* or *B. afzelii*. In a preferred embodiment the antibodies are

raised against an antigenic polypeptide comprising at least 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 75, 100, 125, 150, 175, 200 or more contiguous amino acids of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97. Further, the invention contemplates any range derivable between any of the above-described integers.

The polypeptides of the present invention may be fused with other proteins or peptides. Such fusion polypeptides may be useful for purification or immunodetection purposes, for example. In a preferred embodiment the polypeptides of the invention are expressed as fusions with β -galactosidase, avidin, ubiquitin, *Schistosoma japonicum* glutathione S-transferase, multiple histidines, epitope-tags and the like.

Another aspect of the invention comprises vectors that comprise a nucleic acid encoding all or part of a polypeptide of the present invention. The vectors may, for example, be cloning or expression vectors.

In certain embodiments, it is contemplated that particular advantages will be gained by positioning the nucleic acid sequences of the present invention under the control of a promoter. The promoter may be the promoter that is normally associated with the nucleic acid sequence in its natural environment or it may be a recombinant or heterologous promoter. As used herein, a recombinant or heterologous promoter is intended to refer to a promoter that is not normally associated with a vls gene in its natural environment. Such promoters may include those normally associated with other *Borrelia* polypeptide genes, or promoters isolated from any other bacterial, viral, eukaryotic, or mammalian cell. Naturally, it will be important to employ a promoter that effectively directs the expression of the nucleic acid in the particular cell being used.

The promoters employed may be constitutive, or inducible, and can be used under the appropriate conditions to direct high level or regulated expression of the introduced nucleic acid. In preferred embodiments the promoters are lac, T7, Ara, CMV, RSV LTR, the SV40 promoter alone, or the SV40 promoter in combination with the SV40 enhancer.

Another embodiment is a method of preparing a protein composition comprising growing a recombinant host cell comprising a vector that encodes a polypeptide of the present invention under conditions permitting nucleic acid expression and protein production followed by recovering the protein so produced. The host cell, conditions permitting nucleic acid expression, protein production and recovery, will be known to those of skill in the art, in light of the present disclosure of the vls gene. The recombinant host cell may be a prokaryotic cell or a eukaryotic cell.

VMP-like related proteins and functional variants are also considered part of the invention. Thus it is expected that truncated and mutated versions of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36,

SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97 will afford more convenient and effective forms of polypeptides for treatment regimens. Thus, any functional version of SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97, such as truncated species or homologs, and mutated versions of VMP-like protein are considered as part of the invention.

Another aspect of the invention comprises the recombination of the 14 silent vls cassettes of *B. afzelii* in numerous combinations, providing for example a cocktail of peptide compositions for use as immunogens to develop vaccines for use in Lyme disease and related conditions. Likewise, the 11 silent vls cassettes of *B. garinii* and the 15 silent vls cassettes of *B. burgdorferi* may be recombined in numerous combinations. It is further contemplated by the present invention that these cassettes may be recombined among strains, as well as species of *Borrelia*, providing a cocktail of peptide compositions for use as immunogens to develop vaccines for use in Lyme disease and related conditions.

Pharmaceutical compositions prepared in accordance with the present invention find use in preventing or ameliorating conditions associated with *Borrelia* infections, particularly Lyme disease.

Such methods generally involve administering a pharmaceutical composition comprising an effective amount of a VMP-like antigen of *Borrelia*, such as SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97 or various epitopes thereof.

In certain embodiments of the invention a vaccine may comprise a polynucleotide encoding an antigenic polypeptide. In more specific embodiments the polynucleotide may have a sequence of SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62,

SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, and SEQ ID NO:96 or various fragments thereof. The vaccines of the present invention may comprise multiple polypeptides and/or polynucleotides.

It will also be understood that, if desired, the nucleic acid segment or gene encoding a VMP-like protein could be administered in combination with further agents, such as, proteins or polypeptides or various pharmaceutically active agents. There is virtually no limit to other components which may also be included, given that the additional agents do not cause a significant adverse effect upon contact with the target cells or host tissues.

Therapeutic kits comprising a polypeptide or nucleic acid of the present invention comprise another aspect of the invention. Such kits will generally contain, in suitable container means, a pharmaceutically acceptable formulation of a polypeptide or nucleic acid of the present invention. The kit may have a single container means that contains a polypeptide or nucleic acid of the present invention or it may have distinct container means for the polypeptide or nucleic acid of the present invention and other reagents that may be included within such kits.

The components of the kit may be provided as liquid solution(s), or as dried powder(s). When the components are provided in a liquid solution, the liquid solution is an aqueous solution, with a sterile aqueous solution being particularly preferred. When reagents or components are provided as a dry powder, the powder can be reconstituted by the addition of a suitable solvent. It is envisioned that the solvent may also be provided in another container means.

In another embodiment, the invention provides diagnostic kits. The diagnostic kits may comprise reagents for detecting VMP-like polypeptides or anti-VMP-like antibodies in a sample, such as required for immunoassay. The immunodetection reagent will typically comprise a label associated with the antibody or antigen, or associated with a secondary antibody directed against the first antibody or antigen or a biotin or avidin (or streptavidin) ligand having an associated label. Of course, a number of exemplary labels are known in the art and all such labels may be employed in connection with the present invention. The kits may contain

antibody-label conjugates either in fully conjugated form, in the form of intermediates, or as separate moieties to be conjugated by the user of the kit.

The container means will generally include at least one vial, test tube, flask, bottle, syringe or other container means, into which the antigen or antibody may be placed, and preferably suitably aliquoted. Where a second binding ligand is provided, the kit will also generally contain a second vial or other container into which this ligand or antibody may be placed. The kits of the present invention will also typically include a means for containing the antibody, antigen, and reagent containers in close confinement for commercial sale. Such containers may include injection or blow-molded plastic containers into which the desired vials are retained.

In another aspect, the present invention contemplates an antibody that is immunoreactive with a polypeptide of the invention. An antibody can be a polyclonal or a monoclonal antibody. In a preferred embodiment, an antibody is a monoclonal antibody.

Antibodies, both polyclonal and monoclonal, specific for VMP-like polypeptides and particularly those represented by SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, and SEQ ID NO:97 or variants and epitopes thereof, may be prepared using conventional immunization techniques, as will be generally known to those of skill in the art.

In related embodiments, the invention provides methods of using the antibodies of the invention. In preferred embodiments, the antibodies may be used in immunochemical procedures, such as ELISA and Western blot methods. In other embodiments, the antibodies may be used in purifying native or recombinant VMP-like polypeptides, inhibition studies, and immunolocalization studies.

Table 1 below provides the SEQ ID NO, the GenBank accession number, if any, and a brief description of the sequences described herein.

TABLE 1

SEQ ID NO.	GENBANK NO.	DESCRIPTION
SEQ ID NO: 1	U76405	<i>B. burgdorferi</i> vlsE gene allele vlsE1
SEQ ID NO: 2	AAC45733	Translation of <i>B. burgdorferi</i> vlsE1 gene
SEQ ID NO: 3	L04788	<i>B. hermsii</i> vmp17 gene
SEQ ID NO: 4	AAA22963	Translation of <i>B. hermsii</i> vmp17 gene
SEQ ID NO: 5	AY100629	RT-PCR product of <i>B. afzelii</i> strain ACAI clone 2622 vlsE
SEQ ID NO: 6	AAM77200	Translation of AY100629
SEQ ID NO: 7	AY100630	RT-PCR product of <i>B. afzelii</i> strain ACAI clone 2624a vlsE
SEQ ID NO: 8	AAM77201	Translation of AY100630
SEQ ID NO: 9	AY100631	RT-PCR product of <i>B. afzelii</i> strain ACAI clone 2624b vlsE
SEQ ID NO: 10	AAM77202	Translation of AY100631
SEQ ID NO: 11	AY100632	RT-PCR product of <i>B. afzelii</i> strain ACAI clone 2625 vlsE
SEQ ID NO: 12	AAM77203	Translation of AY100632
SEQ ID NO: 13	AY100634	RT-PCR product of <i>B. garinii</i> strain Ip90 clone 17 vlsE

TABLE 1-continued

SEQ ID NO.	GENBANK NO.	DESCRIPTION
SEQ ID NO: 14	AAM77204	Translation of AY100634
SEQ ID NO: 15	AY100635	RT-PCR product of <i>B. garinii</i> strain Ip90 clone 20 vlsE
SEQ ID NO: 16	AAM77205	Translation of AY100635
SEQ ID NO: 17	AY100636	RT-PCR product of <i>B. garinii</i> strain Ip90 clone 21 vlsE
SEQ ID NO: 18	AAM77206	Translation of AY100636
SEQ ID NO: 19	AY100637	RT-PCR product of <i>B. garinii</i> strain Ip90 clone 23 vlsE
SEQ ID NO: 20	AAM77207	Translation of AY100637
SEQ ID NO: 21	N/A	Primer 4540 (Wang et al., 2001)
SEQ ID NO: 22	N/A	Primer 4548 (Wang et al., 2001)
SEQ ID NO: 23	N/A	Primer 4545 (Wang et al., 2001)
SEQ ID NO: 24	N/A	Primer 4587 (Wang et al., 2001)
SEQ ID NO: 25	N/A	Primer 4588 (Wang et al., 2001)
SEQ ID NO: 26	N/A	Primer 4470 (Wang et al., 2001)
SEQ ID NO: 27	N/A	Primer 4471 (Wang et al., 2001)
SEQ ID NO: 28	AY100633	<i>B. garinii</i> vls silent cassette locus
SEQ ID NO: 29	AY100633	<i>B. garinii</i> upstream ORF
SEQ ID NO: 30	AAN87823	Translation of <i>B. garinii</i> upstream ORF
SEQ ID NO: 31	AY100633	<i>B. garinii</i> 5' vlsE homolog
SEQ ID NO: 32	AAN87824	Translation of <i>B. garinii</i> 5' vlsE homolog
SEQ ID NO: 33	AY100633	<i>B. garinii</i> vls1
SEQ ID NO: 34	AAN87825	Translation of <i>B. garinii</i> vls1
SEQ ID NO: 35	AY100633	<i>B. garinii</i> vls2
SEQ ID NO: 36	AAN87826	Translation of <i>B. garinii</i> vls2
SEQ ID NO: 37	AY100633	<i>B. garinii</i> vls3
SEQ ID NO: 38	AAN87827	Translation of <i>B. garinii</i> vls3
SEQ ID NO: 39	AY100633	<i>B. garinii</i> vls4
SEQ ID NO: 40	AAN87828	Translation of <i>B. garinii</i> vls4
SEQ ID NO: 41	AY100633	<i>B. garinii</i> vls5
SEQ ID NO: 42	AAN87829	Translation of <i>B. garinii</i> vls5
SEQ ID NO: 43	AY100633	<i>B. garinii</i> vls6
SEQ ID NO: 44	AAN87830	Translation of <i>B. garinii</i> vls6
SEQ ID NO: 45	AY100633	<i>B. garinii</i> vls7
SEQ ID NO: 46	AAN87831	Translation of <i>B. garinii</i> vls7
SEQ ID NO: 47	AY100633	<i>B. garinii</i> vls8
SEQ ID NO: 48	AAN87832	Translation of <i>B. garinii</i> vls8
SEQ ID NO: 49	AY100633	<i>B. garinii</i> vls9
SEQ ID NO: 50	AAN87833	Translation of <i>B. garinii</i> vls9
SEQ ID NO: 51	AY100633	<i>B. garinii</i> vls10
SEQ ID NO: 52	AAN87834	Translation of <i>B. garinii</i> vls10
SEQ ID NO: 53	AY100633	<i>B. garinii</i> vls11
SEQ ID NO: 54	AAN87835	Translation of <i>B. garinii</i> vls11
SEQ ID NO: 55	AY100633	<i>B. garinii</i> truncated gene
SEQ ID NO: 56	AAN87823	Translation of <i>B. garinii</i> truncated gene
SEQ ID NO: 57	AY100628	vls silent cassette locus of <i>B. afzelii</i>
SEQ ID NO: 58	AY100628	<i>B. afzelii</i> vls1
SEQ ID NO: 59	AAN87809	Translation of <i>B. afzelii</i> vls1
SEQ ID NO: 60	AY100628	<i>B. afzelii</i> vls2
SEQ ID NO: 61	AAN87810	Translation of <i>B. afzelii</i> vls2
SEQ ID NO: 62	AY100628	<i>B. afzelii</i> vls3
SEQ ID NO: 63	AAN87811	Translation of <i>B. afzelii</i> vls3
SEQ ID NO: 64	AY100628	<i>B. afzelii</i> vls4
SEQ ID NO: 65	AAN87812	Translation of <i>B. afzelii</i> vls4
SEQ ID NO: 66	AY100628	<i>B. afzelii</i> vls5
SEQ ID NO: 67	AAN87813	Translation of <i>B. afzelii</i> vls5
SEQ ID NO: 68	AY100628	<i>B. afzelii</i> vls6
SEQ ID NO: 69	AAN87814	Translation of <i>B. afzelii</i> vls6
SEQ ID NO: 70	AY100628	<i>B. afzelii</i> vls7
SEQ ID NO: 71	AAN87815	Translation of <i>B. afzelii</i> vls7
SEQ ID NO: 72	AY100628	<i>B. afzelii</i> vls8
SEQ ID NO: 73	AAN87816	Translation of <i>B. afzelii</i> vls8
SEQ ID NO: 74	AY100628	<i>B. afzelii</i> vls9a
SEQ ID NO: 75	AAN87817	Translation of <i>B. afzelii</i> vls9a
SEQ ID NO: 76	AY100628	<i>B. afzelii</i> vls10
SEQ ID NO: 77	AAN87818	Translation of <i>B. afzelii</i> vls10
SEQ ID NO: 78	AY100628	<i>B. afzelii</i> vls11
SEQ ID NO: 79	AAN87819	Translation of <i>B. afzelii</i> vls11
SEQ ID NO: 80	AY100628	<i>B. afzelii</i> vls12
SEQ ID NO: 81	AAN87820	Translation of <i>B. afzelii</i> vls12
SEQ ID NO: 82	AY100628	<i>B. afzelii</i> vls13
SEQ ID NO: 83	AAN87821	Translation of <i>B. afzelii</i> vls13
SEQ ID NO: 84	AY100628	<i>B. afzelii</i> vls14
SEQ ID NO: 85	AAN87822	Translation of <i>B. afzelii</i> vls14
SEQ ID NO: 86	AY100628	<i>B. afzelii</i> conserved protein
SEQ ID NO: 87	AAN87823	Translation of <i>B. afzelii</i> conserved protein
SEQ ID NO: 88	N/A	Nucleotides 1-2775 of AY100633 (<i>B. garinii</i>)

TABLE 1-continued

SEQ ID NO.	GENBANK NO.	DESCRIPTION
SEQ ID NO: 89	N/A	Nucleotides 3823-5897 of AY100633 (<i>B. garinii</i>)
SEQ ID NO: 90	N/A	Fragment of <i>B. garinii</i> vls5
SEQ ID NO: 91	N/A	Amino acids 1-184 of AAN87829 (<i>B. garinii</i>)
SEQ ID NO: 92	N/A	Fragment of <i>B. garinii</i> vls8
SEQ ID NO: 93	N/A	Amino acids 56-195 of AAN87832 (<i>B. garinii</i>)
SEQ ID NO: 94	N/A	Expressed ORF in pBG-10-1
SEQ ID NO: 95	N/A	Protein sequence expressed by pBG-10-1
SEQ ID NO: 96	N/A	Expressed ORF in pBA-13-1
SEQ ID NO: 97	N/A	Protein sequence expressed by pBA-13-1
SEQ ID NO: 98	N/A	Primer
SEQ ID NO: 99	N/A	Primer
SEQ ID NO: 100	N/A	Primer
SEQ ID NO: 101	N/A	Primer
SEQ ID NO: 102	N/A	Primer
SEQ ID NO: 103	N/A	Primer
SEQ ID NO: 104	N/A	Primer
SEQ ID NO: 105	N/A	Primer
SEQ ID NO: 106	N/A	17-bp direct repeat of <i>B. burgdorferi</i>
SEQ ID NO: 107	N/A	EcoRI linker

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1B. Arrangement of vls silent cassette regions of *B. garinii* Ip90 and *B. afzelii* ACAI. The orientation of the silent cassettes is indicated by a dashed arrow. Direct repeats are indicated by heavily weighted lines between silent cassettes. The location and orientation of conserved hypothetical protein genes are indicated at the 3' end of each locus. Restriction sites used for cloning and sequencing are also shown. (FIG. 1A) *B. garinii* Ip90. The cross-hatched bar indicates the location of P7-1 clone (Liang and Philipp, 1999) in the vls locus of Ip90. The locations of the telomeric repeat sequences (TRS) and the vlsE-like sequence are shown. (FIG. 1B) *B. afzelii* ACAI. The location and orientation of the vls cassettes and other features of this region are indicated as described above.

FIGS. 2A-2B. Alignment of predicted amino acid sequences of vls silent cassettes of *B. afzelii* ACAI (FIG. 2A) and *B. garinii* Ip90 (FIG. 2B) with the cassette region of *B. burgdorferi* B31 vlsE. Alignment for *B. afzelii* ACAI is based on cassette 1 and for *B. garinii* Ip90 based on cassette 10. The underlined residues at the end of cassette 9 in panel A are a continuation of the cassette following a frameshift. Identical amino acid sequences are shown as periods. The variable regions are indicated by shaded boxes and the lines under the shaded boxes represent the corresponding variable regions of *B. burgdorferi* B31. Gaps and predicted stop codons are indicated as dashes and asterisks, respectively. Cassette 1 (SEQ ID NO:59), cassette 2 (SEQ ID NO:61), cassette 3 (SEQ ID NO:63), cassette 4 (SEQ ID NO:65), cassette 5 (SEQ ID NO:67), cassette 6 (SEQ ID NO:69), cassette 7 (SEQ ID NO:71), cassette 8 (SEQ ID NO:73), cassette 9 (SEQ ID NO:75), cassette 10 (SEQ ID NO:77), cassette 11 (SEQ ID NO:79), cassette 12 (SEQ ID NO:81), cassette 13 (SEQ ID NO:83), cassette 14 (SEQ ID NO:85), cassette B31 vlsE (SEQ ID NO:108).

FIG. 3. RT-PCR of vlsE sequences, using RNA from *B. afzelii* ACAI (lanes 1 and 2) and *B. garinii* Ip90 (lanes 3 and 4) as template. Lanes 2 and 4, with reverse transcriptase; lanes 1 and 3, controls without reverse transcriptase. DNA marker sizes (bp) are indicated on the left.

FIGS. 4A-4B. Alignment of the predicted amino acid sequences based on RT-PCR products from vlsE variants of *B. afzelii* ACAI (FIG. 4A) and *B. garinii* Ip90 (FIG. 4B). Alignments for *B. afzelii* ACAI and *B. garinii* Ip90 are based on the sequences of clones 2622 and 17, respectively. The

variable regions labeled VR-I through VR-VI (FIG. 4A) and VR-II through VR-V (FIG. 4B) are indicated by boxes. Only portions of VR-I and VR-VI are shown for ACAI. Identical amino acid sequences and gaps are shown as periods and dashes, respectively. Solid and dotted bars indicate the predicted minimum and maximum possible recombination events, respectively, resulting in the given vlsE variant. Solid lines indicate 100% sequence identity between the given position in the variant and silent cassette(s) indicated. Dashed lines mark the limits of maximum recombination. Asterisks above certain residues indicate sites of possible point mutations, as explained in the text. In regions where more than one silent cassette matches the variant amino acid sequence, the matches were further analyzed at the nucleotide level. ACAI VlsE Clone 2622 (SEQ ID NO:109), ACAI VlsE Clone 2624a (SEQ ID NO:110), ACAI VlsE Clone 2624b (SEQ ID NO:111), ACAI VlsE Clone 2625 (SEQ ID NO:112), Ip90 VlsE Clone 17 (SEQ ID NO:113), Ip90 VlsE Clone 20 (SEQ ID NO:114), Ip90 VlsE Clone 21 (SEQ ID NO:115), Ip90 VlsE Clone 23 (SEQ ID NO:116).

FIG. 5. Hybridization of plasmid DNA of *B. afzelii* ACAI and *B. garinii* Ip90 with pJRZ53 probe. Lane 1, ACAI plasmid DNA; lane 2, ACAI plasmid DNA digested with EcoRI; lane 3, Ip90 plasmid DNA; and lane 4, Ip90 plasmid DNA digested with EcoRI. The size of EcoRI fragments containing vls sequences are indicated by arrows at left.

FIG. 6. Reactivity of human Lyme disease serum pool and a normal human serum pool with recombinant *Borrelia afzelii* Vls protein VLS-BA13.

FIG. 7. Effect of VLS-BA13 protein concentration on enzyme immunoassay reactivity of serum pools from Lyme disease human subjects and normal human subjects.

FIG. 8. Reactivity of mouse anti-*Borrelia burgdorferi* serum and normal mouse serum with recombinant *Borrelia afzelii* Vls protein VLS-BA13. The reactivity of normal mouse serum was below background levels.

FIG. 9. Effect of VLS-BA13 protein concentration on enzyme immunoassay reactivity of mouse anti-*B. burgdorferi* antiserum and normal mouse serum. The reactivity of normal mouse serum was below background levels.

FIG. 10. Reactivity of human Lyme disease serum pool and a normal human serum pool with recombinant *Borrelia garinii* Vls protein VLS-BG10.

FIG. 11. Effect of VLS-BG10 protein concentration on enzyme immunoassay reactivity of serum pools from Lyme disease human subjects and normal human subjects.

FIG. 12. Reactivity of mouse anti-*Borrelia burgdorferi* serum and normal mouse serum with recombinant *Borrelia garinii* Vls protein VLS-BG10. The reactivity of normal mouse serum was below background levels.

FIG. 13. Effect of VLS-BG10 protein concentration on enzyme immunoassay reactivity of mouse anti-*B. burgdorferi* antiserum and normal mouse serum. The reactivity of normal mouse serum was below background levels.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The present work discloses the identification and characterization of an elaborate genetic system in the Lyme disease spirochete *Borrelia* that promotes extensive antigenic variation of a surface-exposed lipoprotein, VlsE.

Hybridization with the *B. burgdorferi* B31 vls silent cassette sequence in recombinant plasmid pJRZ53 was used in identifying the plasmids and DNA fragments containing vls sequences in *B. garinii* Ip90 and *B. afzelii* ACAI. The pJRZ53 probe hybridized exclusively to plasmids with an approximate size of 28 kb in both ACAI and Ip90. DNA fragments from these *B. garinii* Ip90 and *B. afzelii* ACAI plasmids were inserted into a recombinant lambda bacteriophage vector (lambda-DashI) and sequenced. The results showed *B. garinii* Ip90 to consist of 11 vls silent cassettes and *B. afzelii* ACAI of 14 vls silent cassettes.

With the exception of the junctions at vls3/4 and vls6/7, the 11 vls silent cassettes of Ip90 are flanked by 18 bp direct repeat sequences in the 6 kb region. However, several of these cassettes (vls1, vls4, vls6, and vls11) are truncated (189 to 288 bp in length) relative to the other, full-length cassettes ranging in size from 573 to 594 bp. Unlike Ip90 and B31, the ACAI vls locus is located on an internal EcoRI fragment of a 28-kb linear plasmid, and its location relative to the plasmid telomeres is not known. The ACAI vls locus contained 13 complete and 1 partial silent cassettes with each cassette being flanked by an 18 bp direct repeat sequence.

These silent cassettes share 90% to 97% nucleotide sequence identity with one another within the Ip90 vls locus and 84% to 91% within the ACAI vls locus. Amino acid similarity to the B31 silent cassettes ranges from 51% to 62% for the Ip90 vls silent cassettes and from 50% to 65% for the ACAI vls silent cassettes. The nucleotide sequence and predicted amino acid sequence of vlsE in *B. burgdorferi* is provided in SEQ ID NO:1 and SEQ ID NO:2, respectively. The vlsE expression sites of Ip90 and ACAI have not been isolated, but transcripts of vlsE have been detected by reverse transcriptase PCR for both Ip90 and ACAI. In addition, the occurrence of sequence variation within the vlsE cassette region of these transcripts was verified. Mice infected experimentally with *B. garinii* and *B. afzelii* strains have been shown to express anti-VlsE antibodies (Liang et al., 2000a). Additionally, a protein product of ~35 kDa expressed by *B. garinii* Ip90 reacts with antibodies against IR6, a peptide corresponding to invariant region 6 of the VlsE cassette region (Liang et al., 1999a). The characteristics of the vls loci present in *B. garinii* Ip90 and *B. afzelii* ACAI are therefore similar to those found in *B. burgdorferi* B31.

Genetic variation involved in multi-gene families has been described in several other pathogenic microorganisms (Borst and Geaves, 1987; Borst et al., 1995; Donelson, 1995). In the context of combinatorial recombination, the genetic variation at the vlsE site is similar to that of the pilin-encoding genes of *Neisseria gonorrhoeae* (Seifert and

So, 1988). The gonococcal pilus is primarily composed of repeating subunits of an 18-kilodalton pilin protein and is required for adherence of the bacterium to a variety of human cells (Swanson and Koomey, 1989). While the complete pilin genes are expressed only at two expression sites (pilE1 and pilE2), multiple silent copies (pilS) containing portions of the pilin genes are found over a wide range on the gonococcal chromosome (Haas and Meyer, 1986). Through multiple combinatorial recombination events, a single gonococcal clone expressing one pilin stereotype can give rise to a large number of progeny that express antigenically distinctive pilin variants (Meyer et al., 1982; Hagblom et al., 1985; Segal et al., 1986). The recombination between the expression and silent loci occurs predominantly through a non-reciprocal gene conversion mechanism (Haas and Meyer, 1986; Koomey et al., 1987).

The coding sequences of the *Neisseria* pilin variants are divided into constant, semi-variable, and hypervariable regions (Haas and Meyer, 1986), which are analogous to the conserved and variable regions of the vls cassettes. The constant regions and a conserved DNA sequence (Sma/Cla repeat) located at the 3' end of all pilin loci are thought to pair the regions involved in recombination events (Wainwright et al., 1994). In this context, the 18-bp direct repeats and the conserved regions of the vls cassettes in *B. garinii* and *B. afzelii* may play a similar role in recombination events. The silent loci of gonococcal pilin genes contain different regions of the complete pilin genes (Haas and Meyer, 1986), whereas the silent vls cassettes of *Borrelia* represent only the central cassette region of the vlsE gene.

Non-reciprocal recombinations also occur between the expressed and the silent genes encoding variant surface glycoproteins (VsGs) in African trypanosomes (Donelson, 1995). Based on similarities between the vls locus and the multi-gene families of the other pathogenic microorganisms and experimental data (Zhang and Norris, 1998b), it is likely that a unidirectional gene conversion mechanism is also active in the vls locus. The exact mechanism of vls recombination remains to be determined.

Variation of *Borrelia* surface proteins such as VlsE may also affect the organism's virulence and its ability to adapt to different micro-environments during infection of the mammalian host. Recent studies of a *Borrelia turicatae* mouse infection model that resembles Lyme disease showed that one serotype expressing VmpB exhibited more severe arthritic manifestations, whereas another expressing VmpA had more severe central nervous system involvement. The numbers of *Borrelia* present in the joints and blood of serotype B-infected mice were much higher than those of mice infected with serotype A, consistent with a relationship between Vmp serotype and disease severity. Antigenic variation of *Neisseria* pilin (Lambden et al., 1980; Rudel et al., 1992; Nassif et al., 1993; Jonsson et al., 1994) and Opa proteins (Kupsch et al., 1993) is known to affect adherence of the organisms to human leukocytes and epithelial cells.

A. Antigenic Variation in *B. hermsii*

A complex antigenic variation mechanism has been characterized in *Borrelia hermsii*, a relative of *B. afzelii* and *B. garinii* that causes relapsing fever (Balmelii and Piffatetti, 1996; Barbour, 1993; Donelson, 1995). Surface-exposed lipoproteins called variable major proteins (Vmps) are encoded by homologous genes located in 28- to 32-kb linear plasmids with covalently closed telomeres (Barbour and Garon, 1987; Kitten and Barbour, 1990). The vmp genes have been subdivided into two groups: small and large (Restrepo et al., 1992). Large vmp genes such as vmp7 and vmp17 and small vmp genes such as vmp1 and vmp3 are

approximately 1 kb and 0.6 kb in size, respectively. Each organism contains both small and large vmp genes in an unexpressed (silent) form in the so-called storage plasmids (Plasterk et al., 1985). Only one vmp gene located near one of the telomeres of a different plasmid (called the expression plasmid) is expressed in each organism (Kitten and Barbour, 1990; Barbour et al., 1991a). The nucleotide sequence and predicted amino acid sequence of an expressed vmp gene of *B. hermsii* are provided in SEQ ID NO:3 and SEQ ID NO:4, respectively. Antigenic variation occurs when the expressed vmp is replaced completely or partially by one of the silent vmp genes at the telomeric expression site through interplasmic recombination (Meier et al., 1985; Plasterk et al., 1985; Barbour et al., 1991b), intraplasmic recombination (Restrepo et al., 1994), and post-switch rearrangement (Restrepo and Barbour, 1994). The antigenic switch occurs spontaneously at a frequency of 10^{-3} to 10^{-4} per generation (Stoenner et al., 1982).

B. Identification of Vls

The present invention discloses a repetitive DNA sequence ~500 bp in length, which is present in multiple, nonidentical copies in a 28-kb linear plasmid of infectious *Borrelia burgdorferi*, *Borrelia garinii*, and *Borrelia afzelii*, the causative agents of Lyme disease. These DNA sequences encode polypeptides that have sequence similarity to the Variable Major Proteins (VMPs) of relapsing fever *Borreliae* (such as *B. hermsii*). VMPs are highly antigenic surface proteins, which the relapsing fever *Borreliae* are able to change through a genetic recombination mechanism, thereby evading the immune response. Antibodies against a particular VMP protein are protective, resulting in rapid clearance of bacteria of the corresponding serotype. In *Borrelia burgdorferi*, *Borrelia garinii*, and *Borrelia afzelii*, VMP-like sequences (vls) are present on a 28-kb linear plasmid, and this plasmid appears to encode virulence factor(s) required for infectivity.

C. ELISAs

ELISAs may be used in conjunction with the invention. In an ELISA assay, proteins or peptides incorporating *Borrelia* Vls antigenic sequences are immobilized onto a selected surface, preferably a surface exhibiting a protein affinity such as the wells of a polystyrene microtiter plate. The antigenic proteins or peptides may be isolated or comprised within larger polypeptides. For example, an antigenic Vls peptide may be comprised within a larger polypeptide that also includes a moiety that is useful for anchoring the polypeptide to the selected surface. The anchoring moiety may be an amino acid sequence. Virtually any amino acid sequence may be added to the antigenic Vls sequence so long as it does not confound the results of the ELISA assay. Those of skill in the art would know how to select amino acid sequences that are antigenically neutral with regard to antibodies in the biological sample (including, but not limited to, whole blood, plasma, serum, cerebrospinal fluid, other body fluids, or tissue extracts) that is being tested.

After washing to remove incompletely adsorbed material, it is desirable to bind or coat the assay plate wells with a nonspecific protein that is known to be antigenically neutral with regard to the biological sample such as bovine serum albumin (BSA), casein or solutions of powdered milk. This allows for blocking of nonspecific adsorption sites on the immobilizing surface and thus reduces the background caused by nonspecific binding of antibodies in the biological sample onto the surface.

After binding of antigenic material to the well, coating with a non-reactive material to reduce background, and washing to remove unbound material, the immobilizing

surface is contacted with the antisera or clinical or biological sample to be tested in a manner conducive to immune complex (antigen/antibody) formation. Such conditions preferably include diluting the sample with diluents such as BSA, solution or phosphate buffered saline (PBS)/Tween®. These added agents also tend to assist in the reduction of nonspecific background. The layered biological sample preparation is then allowed to incubate in the well for from about 1 to about 4 hr, at temperatures preferably on the order of about 25° to about 37° C. Following incubation with the diluted or undiluted biological sample, the antisera-contacted surface is washed so as to remove non-immunocomplexed material. A preferred washing procedure includes washing with a solution such as PBS/Tween®.

Following formation of specific immunocomplexes between the test sample and the bound antigen, and subsequent washing, the occurrence and even amount of immunocomplex formation may be determined by subjecting same to a second antibody having specificity for the first. To provide a detecting means, the second antibody will preferably have an associated enzyme that will generate a color development upon incubating with an appropriate chromogenic substrate. Thus, for example, one will desire to contact and incubate the antisera-bound surface with a urease, alkaline phosphatase or peroxidase-conjugated anti-human IgG for a period of time and under conditions which favor the development of immunocomplex formation (e.g., incubation for 2 hr at room temperature in a PBS-containing solution such as PBS/Tween®).

After incubation with the second enzyme-tagged antibody, and subsequent to washing to remove unbound material, the amount of label is quantified by incubation with a chromogenic substrate such as urea and bromocresol purple or 2,2'-azino-di-(3-ethyl-benzthiazoline)-6-sulfonic acid (ABTS) and H₂O₂, in the case of peroxidase as the enzyme label. Quantitation is then achieved by measuring the degree of color generation, e.g., using a visible spectrum spectrophotometer.

Alternatively, the ELISA assay may be performed where antibodies that bind immunologically to *Borrelia* Vls antigenic sequences are immobilized onto a selected surface. After binding of the antibody to the surface, coating with a non-reactive material to reduce background, and washing to remove unbound material, the immobilizing surface is contacted with the biological sample to be tested in a manner conducive to immune complex (antigen/antibody) formation. Following formation of specific immunocomplexes between the test sample and the bound antibody, and subsequent washing, immunocomplex formation may be determined using a second, labeled antibody. This approach enables the detection of an antigen in a biological sample.

D. Epitopic Core Sequences

The present invention is also directed to protein or peptide compositions, free from total cells and other peptides, which comprise a purified protein or peptide which incorporates an epitope that is immunologically cross-reactive with one or more anti-*Borrelia* VMP-like antibodies.

As used herein, the term "incorporating an epitope(s) that is immunologically cross-reactive with one or more anti-VMP-like antibodies" is intended to refer to a peptide or protein antigen which includes a primary, secondary or tertiary structure similar to an epitope located within a *Borrelia* VMP-like polypeptide. The level of similarity will generally be to such a degree that polyclonal antibodies directed against the *Borrelia* VMP-like polypeptide will also bind to, react with, or otherwise recognize, the cross-reactive peptide or protein antigen. Various immunoassay methods

may be employed in conjunction with such antibodies, such as, for example, Western blotting, ELISA, RIA, and the like, all of which are known to those of skill in the art.

The identification of *Borrelia* VMP-like epitopes, and/or their functional equivalents, suitable for use in vaccines is a relatively straightforward matter. For example, one may employ the methods of Hopp, as taught in U.S. Pat. No. 4,554,101, incorporated herein by reference, which teaches the identification and preparation of epitopes from amino acid sequences on the basis of hydrophilicity. The methods described in several other papers, and software programs based thereon, can also be used to identify epitopic core sequences (see, for example, U.S. Pat. No. 4,554,101). The amino acid sequence of these "epitopic core sequences" may then be readily incorporated into peptides, either through the application of peptide synthesis or recombinant technology.

Preferred peptides for use in accordance with the present invention will generally be on the order of about 5 to about 50 amino acids in length, and more preferably about 8 to about 40 amino acids in length. Such peptides may be isolated or comprised within a larger polypeptide. It is proposed that shorter antigenic *Borrelia* VMP-like-derived peptide sequences will provide advantages in certain circumstances, for example, in the preparation of vaccines or in immunologic detection assays. Exemplary advantages include the ease of preparation and purification, the relatively low cost and improved reproducibility of production, and advantageous biodistribution.

It is proposed that particular advantages of the present invention may be realized through the preparation of synthetic peptides which include modified and/or extended epitopic/immunogenic core sequences which result in a "universal" epitopic peptide directed to *Borrelia* VMP-like and *Borrelia* VMP-like-related sequences. It is proposed that these regions represent those which are most likely to promote T-cell or B-cell stimulation in an animal, and, hence, elicit specific antibody production in such an animal.

An epitopic core sequence, as used herein, is a relatively short stretch of amino acids that is "complementary" to, and therefore will bind, antigen binding sites on vls protein-specific antibodies. Additionally or alternatively, an epitopic core sequence is one that will elicit antibodies that are cross-reactive with antibodies directed against the peptide compositions of the present invention. It will be understood that in the context of the present disclosure, the term "complementary" refers to amino acids or peptides that exhibit an attractive force towards each other. Thus, certain epitope core sequences of the present invention may be operationally defined in terms of their ability to compete with or perhaps displace the binding of the desired protein antigen with the corresponding protein-directed antisera.

In general, the size of the polypeptide antigen is not believed to be particularly crucial, so long as it is at least large enough to carry the identified core sequence or sequences. The smallest useful core sequence expected by the present disclosure would generally be on the order of about 5 amino acids in length, with sequences on the order of 8 or 25 being more preferred. Thus, this size will generally correspond to the smallest peptide antigens prepared in accordance with the invention. However, the size of the antigen may be larger where desired, so long as it contains a basic epitopic core sequence.

The identification of epitopic core sequences is known to those of skill in the art, for example, as described in U.S. Pat. No. 4,554,101, incorporated herein by reference, which teaches the identification and preparation of epitopes from amino acid sequences on the basis of hydrophilicity. More-

over, numerous computer programs are available for use in predicting antigenic portions of proteins. Computerized peptide sequence analysis programs (e.g., DNASTar® software, DNASTar, Inc., Madison, Wis.) may also be useful in designing synthetic *Borrelia* VMP-like peptides and peptide analogs in accordance with the present disclosure. In addition, epitope mapping may be performed, in which overlapping peptides corresponding to all regions of the protein are synthesized and tested for reactivity with antibodies directed against vls sequences. Reactivity of serum from animals or humans infected with Lyme disease *Borrelia*, and nonreactivity with serum from animals or patients that do not have Lyme disease would help to define those peptides that react sensitively and specifically with antibodies against Lyme disease *Borrelia*.

An epitopic core sequence may be comprised within a larger polypeptide. For example, an epitopic core sequence of the present invention may be comprised in a larger polypeptide, which also comprises a moiety that is useful for anchoring the polypeptide to the selected surface. The anchoring moiety may be an amino acid sequence. These polypeptides would be particularly useful in the various immunoassay methods of the present invention. In a particular example, a peptide or polypeptide of the present invention may have a cysteine added at one end of the amino acid sequence to permit the addition of biotin. The biotinylated peptides or polypeptides could then be captured on streptavidin-coated surfaces. Those of skill in the art would know how to identify which polypeptides react sensitively and specifically with antibodies against Lyme disease *Borrelia*. For example, reactivity of serum from animals or humans infected with Lyme disease *Borrelia*, and nonreactivity with serum from animals or patients that do not have Lyme disease would help to define those polypeptides that react sensitively and specifically with antibodies against Lyme disease *Borrelia*.

Syntheses of epitopic sequences, or peptides which include an antigenic epitope within their sequence, are readily achieved using conventional synthetic techniques such as the solid phase method (e.g., through the use of commercially available peptide synthesizer such as an Applied Biosystems Model 430A Peptide Synthesizer). Peptide antigens synthesized in this manner may then be aliquoted in predetermined amounts and stored in conventional manners, such as in aqueous solutions or, even more preferably, in a powder or lyophilized state pending use.

In general, due to the relative stability of peptides, they may be readily stored in aqueous solutions for fairly long periods of time if desired, e.g., up to six months or more, in virtually any aqueous solution without appreciable degradation or loss of antigenic activity. However, where extended aqueous storage is contemplated it will generally be desirable to include agents including buffers such as Tris or phosphate buffers to maintain a pH of about 7.0 to about 7.5. Moreover, it may be desirable to include agents which will inhibit microbial growth, such as sodium azide or Merthiolate. For extended storage in an aqueous state it will be desirable to store the solutions at 4° C., or more preferably, frozen. Of course, where the peptides are stored in a lyophilized or powdered state, they may be stored virtually indefinitely, e.g., in metered aliquots that may be rehydrated with a predetermined amount of water (preferably distilled) or buffer prior to use.

E. Antibodies

Means for preparing and characterizing antibodies are well known in the art. An antibody can be a polyclonal or a monoclonal antibody.

The methods for generating monoclonal antibodies (mAbs) generally begin along the same lines as those for preparing polyclonal antibodies. Briefly, a polyclonal antibody is prepared by immunizing an animal with an immunogenic composition in accordance with the present invention and collecting antisera from that immunized animal. A wide range of animal species can be used for the production of antisera. Typically the animal used for production of anti-antisera is a rabbit, a mouse, a rat, a hamster, a guinea pig or a goat. Because of the relatively large blood volume of rabbits, a rabbit is a preferred choice for production of polyclonal antibodies.

As is well known in the art, a given composition may vary in its immunogenicity. It is often necessary therefore to boost the host immune system, as may be achieved by coupling a peptide or polypeptide immunogen to a carrier. Exemplary and preferred carriers are keyhole limpet hemocyanin (KLH) and bovine serum albumin (BSA). Other albumins such as ovalbumin, mouse serum albumin or rabbit serum albumin can also be used as carriers. Means for conjugating a polypeptide to a carrier protein are well known in the art and include glutaraldehyde, m-maleimido-benzoyl-N-hydroxysuccinimide ester, carbodiimide and bis-biazotized benzidine.

As is also well known in the art, the immunogenicity of a particular immunogen composition can be enhanced by the use of non-specific stimulators of the immune response, known as adjuvants. Exemplary and preferred adjuvants include complete Freund's adjuvant (a non-specific stimulator of the immune response containing killed *Mycobacterium tuberculosis*), incomplete Freund's adjuvant and aluminum hydroxide adjuvant.

The amount of immunogen composition used in the production of polyclonal antibodies varies upon the nature of the immunogen as well as the animal used for immunization. A variety of routes can be used to administer the immunogen (subcutaneous, intramuscular, intradermal, intravenous and intraperitoneal). The production of polyclonal antibodies may be monitored by sampling blood of the immunized animal at various points following immunization. A second, booster, injection may also be given. The process of boosting and titering is repeated until a suitable titer is achieved. When a desired level of immunogenicity is obtained, the immunized animal can be bled and the serum isolated and stored, and/or the animal can be used to generate mAbs.

mAbs may be readily prepared through use of well-known techniques, such as those exemplified in U.S. Pat. No. 4,196,265, incorporated herein by reference. Typically, this technique involves immunizing a suitable animal with a selected immunogen composition, e.g., a purified or partially purified LCRF protein, polypeptide or peptide. The immunizing composition is administered in a manner effective to stimulate antibody producing cells. Rodents such as mice and rats are preferred animals, however, the use of rabbit, sheep, or frog cells is also possible. The use of rats may provide certain advantages, but mice are preferred, with the BALB/c mouse being most preferred as this is most routinely used and generally gives a higher percentage of stable fusions.

Following immunization, somatic cells with the potential for producing antibodies, specifically B-lymphocytes (B-cells), are selected for use in the mAb generating protocol. These cells may be obtained from biopsied spleens, tonsils or lymph nodes, or from a peripheral blood sample. Spleen cells and peripheral blood cells are preferred, the former because they are a rich source of antibody-producing

cells that are in the dividing plasmablast stage, and the latter because peripheral blood is easily accessible. Often, a panel of animals will have been immunized and the spleen of an animal with the highest antibody titer will be removed and the spleen lymphocytes obtained by homogenizing the spleen with a syringe. Typically, a spleen from an immunized mouse contains approximately 5×10^7 to 2×10^8 lymphocytes.

The antibody-producing B lymphocytes from the immunized animal are then fused with cells of an immortal myeloma cell, generally one of the same species as the animal that was immunized. Myeloma cell lines suited for use in hybridoma-producing fusion procedures preferably are non-antibody-producing, have high fusion efficiency, and enzyme deficiencies that render them incapable of growing in certain selective media which support the growth of only the desired fused cells (hybridomas).

Any one of a number of myeloma cells may be used, as are known to those of skill in the art. For example, where the immunized animal is a mouse, one may use P3-X63/Ag8, X63-Ag8.653, NS1/1.Ag 4 1, Sp210-Ag14, FO, NSO/U, MPC-11, MPC11-X45-GTG 1.7 and S194/5XX0 Bul; for rats, one may use R210.RCY3, Y3-Ag 1.2.3, IR983F and 4B210; and U-266, GM1500-GRG2, LICR-LON-HMy2 and UC729-6 are all useful in connection with human cell fusions.

One preferred murine myeloma cell is the NS-1 myeloma cell line (also termed P3-NS-1-Ag4-1), which is readily available from the NIGMS Human Genetic Mutant Cell Repository by requesting cell line repository number GM3573. Another mouse myeloma cell line that may be used is the 8-azaguanine-resistant mouse murine myeloma SP2/0 non-producer cell line.

Methods for generating hybrids of antibody-producing spleen or lymph node cells and myeloma cells usually comprise mixing somatic cells with myeloma cells in a 2:1 ratio, though the ratio may vary from about 20:1 to about 1:1, respectively, in the presence of an agent or agents (chemical or electrical) that promote the fusion of cell membranes. Fusion methods using Sendai virus have been described, and those using polyethylene glycol (PEG), such as 37% (v/v) PEG. The use of electrically induced fusion methods is also appropriate.

Fusion procedures usually produce viable hybrids at low frequencies, about 1×10^{-6} to 1×10^{-8} . However, this does not pose a problem, as the viable, fused hybrids are differentiated from the parental, unfused cells (particularly the unfused myeloma cells that would normally continue to divide indefinitely) by culturing in a selective medium. The selective medium is generally one that contains an agent that blocks the de novo synthesis of nucleotides in the tissue culture media. Exemplary and preferred agents are aminopterin, methotrexate, and azaserine. Aminopterin and methotrexate block de novo synthesis of both purines and pyrimidines, whereas azaserine blocks only purine synthesis. Where aminopterin or methotrexate is used, the media is supplemented with hypoxanthine and thymidine as a source of nucleotides (HAT medium). Where azaserine is used, the media is supplemented with hypoxanthine.

The preferred selection medium is HAT. Only cells capable of operating nucleotide salvage pathways are able to survive in HAT medium. The myeloma cells are defective in key enzymes of the salvage pathway, e.g., hypoxanthine phosphoribosyl transferase (HPRT), and they cannot survive. The B-cells can operate this pathway, but they have a limited life span in culture and generally die within about

two weeks. Therefore, the only cells that can survive in the selective media are those hybrids formed from myeloma and B-cells.

This culturing provides a population of hybridomas from which specific hybridomas are selected. Typically, selection of hybridomas is performed by culturing the cells by single-clone dilution in microtiter plates, followed by testing the individual clonal supernatants (after about two to three weeks) for the desired reactivity. The assay should be sensitive, simple and rapid, such as radioimmunoassays, enzyme immunoassays, cytotoxicity assays, plaque assays, dot immunobinding assays, and the like.

The selected hybridomas would then be serially diluted and cloned into individual antibody-producing cell lines, which clones can then be propagated indefinitely to provide mAbs. The cell lines may be exploited for mAb production in two basic ways. A sample of the hybridoma can be injected (often into the peritoneal cavity) into a histocompatible animal of the type that was used to provide the somatic and myeloma cells for the original fusion. The injected animal develops tumors secreting the specific monoclonal antibody produced by the fused cell hybrid. The body fluids of the animal, such as serum or ascites fluid, can then be tapped to provide mAbs in high concentration. The individual cell lines could also be cultured in vitro, where the mAbs are naturally secreted into the culture medium from which they can be readily obtained in high concentrations. mAbs produced by either means may be further purified, if desired, using filtration, centrifugation and various chromatographic methods such as HPLC or affinity chromatography.

F. Immunoprecipitation

The antibodies of the present invention are particularly useful for the isolation of antigens by immunoprecipitation. Immunoprecipitation involves the separation of the target antigen-antibody complexes from a complex mixture, and is used to discriminate or isolate minute amounts of protein. For the isolation of membrane proteins cells must be solubilized into detergent micelles. Nonionic detergents are preferred, since other agents, such as bile salts, precipitate at acid pH or in the presence of bivalent cations.

In an alternative embodiment the antibodies of the present invention are useful for the close juxtaposition of two antigens. This is particularly useful for increasing the localized concentration of antigens, e.g., enzyme-substrate pairs.

G. Western Blots

The compositions of the present invention will find great use in immunoblot or western blot analysis. The anti-*Borrelia* VMP-like antibodies may be used as high-affinity primary reagents for the identification of proteins immobilized onto a solid support matrix, such as nitrocellulose, nylon or combinations thereof. In conjunction with immunoprecipitation, followed by gel electrophoresis, these may be used as a single step reagent for use in detecting antigens against which secondary reagents used in the detection of the antigen cause an adverse background. This is especially useful when the antigens studied are immunoglobulins (precluding the use of immunoglobulins binding bacterial cell wall components), the antigens studied cross-react with the detecting agent, or they migrate at the same relative molecular weight as a cross-reacting signal.

Immunologically-based detection methods for use in conjunction with Western blotting include enzymatically-, radiolabel-, or fluorescently-tagged secondary antibodies against the toxin moiety are considered to be of particular use in this regard.

H. Vaccines

An important aspect of the invention is the recognition that *Borrelia* VMP-like sequences recombine at the vlsE site, with the result that antigenic variation is virtually limitless. Multiclonal populations therefore can exist in an infected patient so that immunological defenses are severely tested if not totally overwhelmed. Thus there is now the opportunity to develop more effective combinations of immunogens for protection against *Borrelia* infections or as preventive inoculations such as in the form of cocktails of multiple antigenic variants based on a series of combinatorial VMP-like antigens.

VMP-like protein preparations may be administered in several ways, either locally or systemically in pharmaceutically acceptable formulations. Amounts appropriate for administration are determined on an individual basis depending on such factors as age and sex of the subject, as well as physical condition and weight. Such determinations are well within the skill of the practitioner in the medical field.

Other methods of administration may include injection of *Borrelia* VMP-like DNAs into vaccine recipients (human or animal) driven by an appropriate promoter such as CMV, (so called DNA vaccines). Such preparations could be injected subcutaneously or intramuscularly, administered orally, or introduced into the skin on metal particles propelled by high-pressure gas. DNA vaccination techniques are currently well past the initial development stage and have shown promise as vaccination strategies.

The present invention contemplates vaccines for use in both active and passive immunization embodiments. Immunogenic compositions, proposed to be suitable for use as a vaccine, may be prepared most directly from immunogenic *Borrelia* VMP-like peptides prepared in a manner disclosed herein. Preferably the antigenic material is extensively dialyzed to remove undesired small molecular weight molecules and/or lyophilized for more ready formulation into a desired vehicle.

The preparation of vaccines which contain *Borrelia* VMP-like peptide or polypeptide sequences as active ingredients is generally well understood in the art, as exemplified by U.S. Pat. Nos. 4,608,251; 4,601,903; 4,599,231; 4,599,230; 4,596,792; and 4,578,770, all incorporated herein by reference. Typically, such vaccines are prepared as injectables. Either as liquid solutions or suspensions: solid forms suitable for solution in, or suspension in, liquid prior to injection may also be prepared. The preparation may also be emulsified. The active immunogenic ingredient is often mixed with excipients which are pharmaceutically acceptable and compatible with the active ingredient. Suitable excipients are, for example, water, saline, dextrose, glycerol, ethanol, or the like and combinations thereof. In addition, if desired, the vaccine may contain auxiliary substances such as wetting or emulsifying agents, pH buffering agents, or adjuvants which enhance the effectiveness of the vaccines.

Vaccines may be conventionally administered parenterally, by injection, for example, either subcutaneously or intramuscularly. Vaccines may also be administered orally. Oral formulations include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate and the like. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and contain about 10 to about 95% of active ingredient, preferably about 25 to about 70%.

The *Borrelia* VMP-like-derived peptides or polypeptides of the present invention may be formulated into the vaccine

as neutral or salt forms. It is anticipated that many VMP-like-derived peptides or polypeptides with different sequences could be incorporated into a single vaccine, in effect producing a combinatorial vaccine. Pharmaceutically-acceptable salts, include the acid addition salts (formed with the free amino groups of the peptide) and those which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups may also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, 2-ethylamino ethanol, histidine, procaine, and the like.

The vaccines are administered in a manner compatible with the dosage formulation, and in such amount as will be therapeutically effective and immunogenic. The quantity to be administered depends on the subject to be treated, including, e.g., the capacity of the individual's immune system to synthesize antibodies, and the degree of protection desired. Precise amounts of active ingredient required to be administered depend on the judgment of the practitioner. However, suitable dosage ranges are of the order of several hundred micrograms active ingredient per vaccination. Suitable regimes for initial administration and booster shots are also variable, but are typified by an initial administration followed by subsequent inoculations or other administrations.

The manner of application may be varied widely. Any of the conventional methods for administration of a vaccine are applicable. These are believed to include oral application on a solid physiologically acceptable base or in a physiologically acceptable dispersion, parenterally, by injection or the like. The dosage of the vaccine will depend on the route of administration and will vary according to the size of the host.

Various methods of achieving adjuvant effect for the vaccine includes use of agents such as aluminum hydroxide or phosphate (alum), commonly used as about 0.05 to about 0.1% solution in phosphate buffered saline, admixture with synthetic polymers of sugars (Carbopol®) used as an about 0.25% solution, aggregation of the protein in the vaccine by heat treatment with temperatures ranging between about 70° to about 101° C. for a 30-second to 2-minute period, respectively. Aggregation by reactivating with pepsin treated (Fab) antibodies to albumin, mixture with bacterial cells such as *C. parvum* or endotoxins or lipopolysaccharide components of Gram-negative bacteria, emulsion in physiologically acceptable oil vehicles such as mannide mono-oleate (Aracel A) or emulsion with a 20% solution of a perfluorocarbon (Fluosol-DA®) used as a block substitute may also be employed.

In many instances, it will be desirable to have multiple administrations of the vaccine, usually not exceeding six vaccinations, more usually not exceeding four vaccinations and preferably one or more, usually at least about three to twelve week intervals, more usually from three to five week intervals. Periodic boosters at intervals of 1-5 years, usually three years, will be desirable to maintain protective levels of the antibodies. The course of the immunization may be followed by assays for antibodies for the supernatant antigens. The assays may be performed by labeling with conventional labels, such as radionucleotides, enzymes, fluorescents, and the like. These techniques are well known and may be found in a wide variety of patents, such as U.S. Pat. Nos. 3,791,932; 4,174,384 and 3,949,064, as illustrative of these types of assays.

I. Nucleic Acids

The present invention provides the nucleotide sequences of the vls gene in *B. garinii* and *B. afzelii*. It is contemplated that the isolated nucleic acids of the present invention may be put under the control of a promoter. The promoter may be the promoter that is naturally associated with the vls gene or it may be a recombinant or heterologous promoter. As used herein, a recombinant or heterologous promoter is intended to refer to a promoter that is not normally associated with a DNA segment encoding a *Borrelia* VMP-like peptide in its natural environment. Such promoters may include promoters normally associated with other genes, and/or promoters isolated from any viral, prokaryotic (e.g., bacterial), eukaryotic (e.g., fungal, yeast, plant, or animal) cell.

Naturally, it will be important to employ a promoter that effectively directs the expression of the DNA segment in the cell type, organism, or even animal, chosen for expression. The use of promoter and cell type combinations for protein expression is generally known to those of skill in the art of molecular biology, for example, see Sambrook et al., 2001. The promoters employed may be constitutive, or inducible, and can be used under the appropriate conditions to direct high level expression of the introduced DNA segment, such as is advantageous in the large-scale production of recombinant proteins or peptides. Appropriate promoter/expression systems contemplated for use in high-level expression include, but are not limited to, the *Pichia* expression vector system (Pharmacia LKB Biotechnology), a baculovirus system for expression in insect cells, or any suitable yeast or bacterial expression system.

In connection with expression embodiments to prepare recombinant proteins and peptides, it is contemplated that longer DNA segments will most often be used, with DNA segments encoding the entire peptide sequence being most preferred. However, it will be appreciated that the use of shorter DNA segments to direct the expression of *Borrelia* VMP-like peptides or epitopic core regions, such as may be used to generate anti-*Borrelia* VMP-like antibodies, also falls within the scope of the invention. DNA segments that encode *Borrelia* VMP-like peptide antigens from about 10 to about 100 amino acids in length, or more preferably, from about 20 to about 80 amino acids in length, or even more preferably, from about 30 to about 70 amino acids in length are contemplated to be particularly useful.

In addition to their use in directing the expression of *Borrelia* VMP-like peptides of the present invention, the nucleic acid sequences contemplated herein also have a variety of other uses. For example, they also have utility as probes or primers in nucleic acid hybridization embodiments. As such, it is contemplated that nucleic acid segments that comprise a sequence region that consists of at least about a 10, 11, 12, 13, 14, 15, 16, 17, 18, or 19 nucleotide long contiguous sequence that has the same sequence as, or is complementary to, an about 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 nucleotide long contiguous DNA segment of SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94,

and SEQ ID NO:96 will find particular utility. Longer contiguous identical or complementary sequences, e.g., those of about 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 125, 150, 175, 200, 300, 400, 500, (including all intermediate lengths) and those up to and including full-length sequences will also be of use in certain embodiments.

The ability of such nucleic acid probes to specifically hybridize to *Borrelia* VMP-like-encoding sequences will enable them to be of use in detecting the presence of complementary sequences in a given sample. However, other uses are envisioned, including the use of the sequence information for the preparation of mutant species primers, or primers for use in preparing other genetic constructions.

Nucleic acid molecules having sequence regions consisting of contiguous nucleotide stretches of about 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 125, 150, 175, 200, 300, 400, 500 or more, identical or complementary to the DNA sequence of SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, and SEQ ID NO:96, are particularly contemplated as hybridization probes for use in, e.g., Southern and Northern blotting. Smaller fragments will generally find use in hybridization embodiments, wherein the length of the contiguous complementary region may be varied, such as between about 10-14 and up to about 100 nucleotides, but larger contiguous complementary stretches may be used, according to the length complementary sequences one wishes to detect.

The use of a hybridization probe of about 14 nucleotides in length allows the formation of a duplex molecule that is both stable and selective. Molecules having contiguous complementary sequences over stretches greater than 14 bases in length are generally preferred, though, in order to increase stability and selectivity of the hybrid, and thereby improve the quality and degree of specific hybrid molecules obtained. One will generally prefer to design nucleic acid molecules having gene-complementary stretches of about 15 to about 20 contiguous nucleotides, or even longer where desired.

Of course, fragments may also be obtained by other techniques such as, e.g., by mechanical shearing or by restriction enzyme digestion. Small nucleic acid segments or fragments may be readily prepared by, for example, directly synthesizing the fragment by chemical means, as is commonly practiced using an automated oligonucleotide syn-

thesizer. Also, fragments may be obtained by application of nucleic acid reproduction technology, such as PCR™, by introducing selected sequences into recombinant vectors for recombinant production, and by other recombinant DNA techniques generally known to those of skill in the art of molecular biology.

Accordingly, the nucleotide sequences of the invention may be used for their ability to selectively form duplex molecules with complementary stretches of DNA fragments. Depending on the application envisioned, one will desire to employ varying conditions of hybridization to achieve varying degrees of selectivity of probe towards target sequence. For applications requiring high selectivity, one will typically desire to employ relatively stringent conditions to form the hybrids, e.g., conditions of high stringency where one will select relatively low salt and/or high temperature conditions, such as provided by about 0.02 M to about 0.15 M NaCl at temperatures of about 50° C. to about 70° C. Such selective conditions tolerate little, if any, mismatch between the probe and the template or target strand, and would be particularly suitable for isolating *Borrelia* VMP-like-encoding DNA segments. Detection of DNA segments via hybridization is well-known to those of skill in the art, and the teachings of U.S. Pat. Nos. 4,965,188 and 5,176,995 (each incorporated herein by reference) are exemplary of the methods of hybridization analyses.

Of course, for some applications, for example, where one desires to prepare mutants employing a mutant primer strand hybridized to an underlying template or where one seeks to isolate *Borrelia* VMP-like-encoding sequences from related species, functional equivalents, or the like, less stringent hybridization conditions will typically be needed in order to allow formation of the heteroduplex. In these circumstances, one may desire to employ conditions such as about 0.15 M to about 0.9 M salt, at temperatures ranging from about 20° C. to about 55° C. Cross-hybridizing species can thereby be readily identified as positively hybridizing signals with respect to control hybridizations. In any case, it is generally appreciated that conditions can be rendered more stringent by the addition of increasing amounts of formamide, which serves to destabilize the hybrid duplex in the same manner as increased temperature. Thus, hybridization conditions can be readily manipulated, and thus will generally be a method of choice depending on the desired results.

In certain embodiments, it will be advantageous to employ nucleic acid sequences of the present invention in combination with an appropriate means, such as a label, for determining hybridization. A wide variety of appropriate indicator means are known in the art, including fluorescent, radioactive, enzymatic or other ligands, such as avidin/biotin, which are capable of giving a detectable signal. In preferred embodiments, one will likely desire to employ a fluorescent label or an enzyme tag, such as urease, alkaline phosphatase or peroxidase, instead of radioactive or other environmental undesirable reagents. In the case of enzyme tags, colorimetric indicator substrates are known that can be employed to provide a means visible to the human eye or spectrophotometrically, to identify specific hybridization with complementary nucleic acid-containing samples.

In general, it is envisioned that the hybridization probes described herein will be useful both as reagents in solution hybridization as well as in embodiments employing a solid phase. In embodiments involving a solid phase, the test DNA (or RNA) is adsorbed or otherwise affixed to a selected matrix or surface. This fixed, single-stranded nucleic acid is then subjected to specific hybridization with selected probes under desired conditions. The selected conditions will

depend on the particular circumstances based on the particular criteria required (depending, for example, on the G+C content, type of target nucleic acid, source of nucleic acid, size of hybridization probe, etc.). Following washing of the hybridized surface so as to remove nonspecifically bound probe molecules, specific hybridization is detected, or even quantitated, by means of the label.

Isolated nucleic acids encoding vls or vls-related genes are contemplated to be particularly useful in connection with this invention. Any recombinant vls combining any of the vlsE expression site loci and/or silent vls cassette would likewise be very useful with the methods of the invention.

Isolation of the DNA encoding VMP-like polypeptides allows one to use methods well known to those of skill in the art, and as herein described, to make changes in the codons for specific amino acids such that the codons are "preferred usage" codons for a given species. Thus for example, preferred codons will vary significantly for bacterial species as compared with mammalian species; however, there are preferences even among related species. Shown below is a preferred codon usage table for humans. Isolation of spirochete DNA encoding VMP-like proteins will allow substitutions for preferred human codons, although expressed polypeptide product from human DNA is expected to be homologous to bacterial VMP-like proteins and so would be expected to be structurally and functionally equivalent to VMP-like proteins isolated from a spirochete. However, substitutions of preferred human codons may improve expression in the human host, thereby improving the efficiency of potential DNA vaccines. This method may also be useful in achieving improved expression of the recombinant VMP-like protein in *E. coli* or any of a variety of prokaryotic and eukaryotic cells.

TABLE 2

Codon Frequency in <i>Homo sapiens</i>											
Codon	v^b	Total # ^a	Codon	v^b	Total # ^a	Codon	v^b	Total # ^a	Codon	v^b	Total # ^a
UUU	16.6	72711	UCU	14.0	62953	UAU	12.3	55039	UGU	9.5	42692
UUC	21.4	95962	UCC	17.7	79482	UAC	17.0	76480	UGC	12.8	57368
UUA	6.3	28202	UCA	10.7	48225	UAA	0.7	2955	UGA	1.2	5481
UUG	11.5	51496	UCG	4.4	19640	UAG	0.5	2181	UGG	13.5	59982
CUU	11.7	52401	CCU	16.7	74975	CAU	9.6	43193	CGU	4.6	20792
CUC	19.5	87696	CCC	20.0	89974	CAC	14.6	65533	CGC	11.0	49507
CUA	6.3	28474	CCA	16.2	72711	CAA	11.4	51146	CGA	5.9	26551
CUG	40.6	182139	CCG	6.9	30863	CAG	33.7	151070	CGG	11.3	50682
AUU	15.7	70652	ACU	12.8	57288	AAU	16.6	74401	AGU	11.1	49894
AUC	23.7	106390	ACC	21.1	94793	AAC	21.1	94725	AGC	19.1	85754
AUA	6.7	30139	ACA	14.7	66136	AAA	23.2	104221	AGA	10.8	48369
AUG	22.6	101326	ACG	6.7	30059	AAG	33.9	152179	AGG	10.9	48882
GUU	10.6	47805	GCU	18.7	83800	GAU	22.0	98712	GCU	11.2	50125
GUC	15.6	70189	GCC	29.2	130966	GAC	27.0	121005	GGC	24.0	107571
GUA	6.6	29659	GCA	15.3	68653	GAA	27.8	124852	GGA	16.9	75708
GUG	30.0	134750	GCG	7.5	33759	GAG	40.8	182943	GGG	16.7	74859

Coding GC 52.96% 1st letter GC 55.98% 2nd letter GC 42.29% 3rd letter GC 60.60%

^aTotal 4489120

^b v = Frequency per 1000

The definition of a "VMP-like sequence" or "VMP-related gene" as used herein, is a gene that hybridizes, under relatively stringent hybridization conditions (see, e.g., Sambrook et al., 2001), to DNA sequences presently known to include related gene sequences.

To prepare a VMP-like gene segment or cDNA one may follow the teachings disclosed herein and also the teachings of any patents or scientific documents specifically referenced herein. One may obtain a rVMP- or other related-encoding DNA segments using molecular biological techniques, such as polymerase chain reaction (PCR™) or

screening of a cDNA or genomic library, using primers or probes with sequences based on the above nucleotide sequence. Such single- or double-stranded DNA segments may be readily prepared by, for example, directly synthesizing the fragments by chemical means, by application of nucleic acid reproduction technology, such as the PCR™ technology of U.S. Pat. Nos. 4,683,195 and 4,683,202 (herein incorporated by reference). The practice of these techniques is a routine matter for those of skill in the art, as taught in various scientific texts (see e.g., Sambrook et al., 2001), incorporated herein by reference. Certain documents further particularly describe suitable mammalian expression vectors, e.g., U.S. Pat. No. 5,168,050, incorporated herein by reference. The VMP-like genes and DNA segments that are particularly preferred for use in certain aspects of the present methods are those encoding VMP-like and VMP-related polypeptides.

It is also contemplated that one may clone other additional genes or cDNAs that encode a VMP-like or VMP-related peptide, protein or polypeptide. The techniques for cloning DNA molecules, i.e., obtaining a specific coding sequence from a DNA library that is distinct from other portions of DNA, are well known in the art. This can be achieved by, for example, screening an appropriate DNA library which relates to the cloning of a vls gene such as from the variable region of that gene. The screening procedure may be based on the hybridization of oligonucleotide probes, designed from a consideration of portions of the amino acid sequence of known DNA sequences encoding related *Borrelia* proteins. The operation of such screening protocols is well known to those of skill in the art and are described in detail in the scientific literature, for example, see Sambrook et al., 2001.

Techniques for introducing changes in nucleotide sequences that are designed to alter the functional properties of the encoded proteins or polypeptides are well known in the art, e.g., U.S. Pat. No. 4,518,584, incorporated herein by reference, which techniques are also described in further detail herein. Such modifications include the deletion, insertion or substitution of bases, which may or may not result in changes in the amino acid sequence. Changes may be made to increase the activity of a protein, to increase its biological stability or half-life, to change its glycosylation pattern, and

the like. All such modifications to the nucleotide sequences are encompassed by this invention.

I. Biological Functional Equivalents

Modification and changes may be made in the structure of the peptides of the present invention and DNA segments which encode them and still obtain a functional molecule that encodes a protein or peptide with desirable characteristics. The following is a discussion based upon changing the amino acids of a protein to create an equivalent, or even an improved, second-generation molecule. The amino acid changes may be achieved by changing the codons of the DNA sequence, according to the following codon table:

TABLE 3

Amino Acids			Codons			
Alanine	Ala	A	GCA	GCC	GCG	GCU
Cysteine	Cys	C	UGC	UGU		
Aspartic acid	Asp	D	GAC	GAU		
Glutamic acid	Glu	E	GAA	GAG		
Phenylalanine	Phe	F	UUC	UUU		
Glycine	Gly	G	GGA	GGC	GGG	GGU
Histidine	His	H	CAC	CAU		
Isoleucine	Ile	I	AUA	AUC	AUU	
Lysine	Lys	K	AAA	AAG		
Leucine	Leu	L	UUA	UUG	CUA	CUC CUG CUU
Methionine	Met	M	AUG			
Asparagine	Asn	N	AAC	AAU		
Proline	Pro	P	CCA	CCC	CCG	CCU
Glutamine	Gln	Q	CAA	CAG		
Arginine	Arg	R	AGA	AGG	CGA	CGC CGG CGU
Serine	Ser	S	AGC	AGU	UCA	UCC UCG UCU
Threonine	Thr	T	ACA	ACC	ACG	ACU
Valine	Val	V	GUA	GUC	GUG	GUU
Tryptophan	Trp	W	UGG			
Tyrosine	Tyr	Y	UAC	UAU		

For example, certain amino acids may be substituted for other amino acids in a protein structure without appreciable loss of interactive binding capacity with structures such as, for example, antigen-binding regions of antibodies or binding sites on substrate molecules. Since it is the interactive capacity and nature of a protein that defines that protein's biological functional activity, certain amino acid sequence substitutions can be made in a protein sequence, and, of course, its underlying DNA coding sequence, and nevertheless obtain a protein with like properties. It is thus contemplated by the inventors that various changes may be made in the peptide sequences of the disclosed compositions, or corresponding DNA sequences which encode said peptides without appreciable loss of their biological utility or activity.

In making such changes, the hydropathic index of amino acids may be considered. The importance of the hydropathic amino acid index in conferring interactive biologic function on a protein is generally understood in the art. It is accepted that the relative hydropathic character of the amino acid contributes to the secondary structure of the resultant protein, which in turn defines the interaction of the protein with other molecules, for example, enzymes, substrates, receptors, DNA, antibodies, antigens, and the like.

Each amino acid has been assigned a hydropathic index on the basis of their hydrophobicity and charge characteristics, these are: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6); histidine (-3.2); glutamate (-3.5); glutamine (-3.5); aspartate (-3.5); asparagine (-3.5); lysine (-3.9); and arginine (-4.5).

It is known in the art that certain amino acids may be substituted by other amino acids having a similar hydropathic index or score and still result in a protein with similar biological activity, i.e., still obtain a biologically equivalent protein. In making such changes, the substitution of amino acids whose hydropathic indices are within ± 2 is preferred, those which are within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

It is also understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity. U.S. Pat. No. 4,554,101, incorporated herein by reference, states that the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with a biological property of the protein.

As detailed in U.S. Pat. No. 4,554,101, the following hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0 \pm 1); glutamate (+3.0 \pm 1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (-0.4); proline (-0.5 \pm 1); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5); tryptophan (-3.4).

It is understood that an amino acid can be substituted for another having a similar hydrophilicity value and still obtain a biologically equivalent, and in particular, an immunologically equivalent protein. In such changes, the substitution of amino acids whose hydrophilicity values are within ± 2 is preferred, those which are within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

As outlined above, amino acid substitutions are generally therefore based on the relative similarity of the amino acid side-chain substituents, for example, their hydrophobicity, hydrophilicity, charge, size, and the like. Exemplary substitutions which take various of the foregoing characteristics into consideration are well known to those of skill in the art and include: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine; and valine, leucine and isoleucine.

J. Site-Specific Mutagenesis

Site-specific mutagenesis is a technique useful in the preparation of individual peptides, or biologically functional equivalent proteins or peptides, through specific mutagenesis of the underlying DNA. The technique further provides a ready ability to prepare and test sequence variants, for example, incorporating one or more of the foregoing considerations, by introducing one or more nucleotide sequence changes into the DNA. Site-specific mutagenesis allows the production of mutants through the use of specific oligonucleotide sequences which encode the DNA sequence of the desired mutation, as well as a sufficient number of adjacent nucleotides, to provide a primer sequence of sufficient size and sequence complexity to form a stable duplex on both sides of the deletion junction being traversed. Typically, a primer of about 17 to 25 nucleotides in length is preferred, with about 1 to 10 residues on both sides of the junction of the sequence being altered.

In general, the technique of site-specific mutagenesis is well known in the art, as exemplified by various publications. As will be appreciated, the technique typically employs a phage vector which exists in both a single stranded and double stranded form. Typical vectors useful in site-directed mutagenesis include vectors such as the M13 phage. These phage are readily commercially available and their use is generally well known to those skilled in the art.

Double stranded plasmids are also routinely employed in site directed mutagenesis which eliminates the step of transferring the gene of interest from a plasmid to a phage.

In general, site-directed mutagenesis in accordance herewith is performed by first obtaining a single-stranded vector or melting apart of two strands of a double stranded vector which includes within its sequence a DNA sequence which encodes the desired peptide. An oligonucleotide primer bearing the desired mutated sequence is prepared, generally synthetically. This primer is then annealed with the single-stranded vector, and subjected to DNA polymerizing enzymes such as *E. coli* polymerase I Klenow fragment, in order to complete the synthesis of the mutation-bearing strand. Thus, a heteroduplex is formed wherein one strand encodes the original non-mutated sequence and the second strand bears the desired mutation. This heteroduplex vector is then used to transform appropriate cells, such as *E. coli* cells, and clones are selected which include recombinant vectors bearing the mutated sequence arrangement.

The preparation of sequence variants of the selected peptide-encoding DNA segments using site-directed mutagenesis is provided as a means of producing potentially useful species and is not meant to be limiting as there are other ways in which sequence variants of peptides and the DNA sequences encoding them may be obtained. For example, recombinant vectors encoding the desired peptide sequence may be treated with mutagenic agents, such as hydroxylamine, to obtain sequence variants.

H. Expression of VMP-like Proteins

A particular aspect of this invention provides novel ways in which to utilize VMP-like DNA segments and recombinant vectors comprising vls DNA segments. As is well known to those of skill in the art, many such vectors are readily available, one particular detailed example of a suitable vector for expression in mammalian cells is that described in U.S. Pat. No. 5,168,050, incorporated herein by reference. However, there is no requirement that a highly purified vector be used, so long as the coding segment employed encodes a VMP-like protein and does not include any coding or regulatory sequences that would have an adverse effect on cells. Therefore, it will also be understood that useful nucleic acid sequences may include additional residues, such as additional non-coding sequences flanking either of the 5' or 3' portions of the coding including, for example, promoter regions, or may include various internal sequences, i.e., introns, which are known to occur within genes.

After identifying an appropriate VMP-encoding gene or DNA molecule, it may be inserted into any one of the many vectors currently known in the art, so that it will direct the expression and production of the VMP-like protein when incorporated into a host cell. In a recombinant expression vector, the coding portion of the DNA segment is positioned under the control of a promoter. The promoter may be in the form of the promoter which is naturally associated with a VMP-encoding gene, as may be obtained by isolating the 5' non-coding sequences located upstream of the coding segment, for example, using recombinant cloning and/or PCR™ technology, in connection with the compositions disclosed herein.

The use of recombinant promoters to achieve protein expression is generally known to those of skill in the art of molecular biology, for example, see Sambrook et al., (2001).

For the expression of VMP-like proteins, once a suitable (full-length if desired) clone or clones have been obtained, whether they be cDNA based or genomic, one may proceed to prepare an expression system for the recombinant prepa-

ration of VMP-like proteins. The engineering of DNA segment(s) for expression in a prokaryotic or eukaryotic system may be performed by techniques generally known to those of skill in recombinant expression. It is believed that virtually any expression system may be employed in the expression of VMP-like proteins.

VMP-like proteins may be successfully expressed in eukaryotic expression systems, however, it is also envisioned that bacterial expression systems may be preferred for the preparation of VMP-like proteins for all purposes. The DNA or cDNA encoding VMP-like proteins may be separately expressed in bacterial systems, with the encoded proteins being expressed as fusions with beta-galactosidase, ubiquitin, *Schistosoma japonicum* glutathione S-transferase, green fluorescent protein, polyhistidine and the like. It is believed that bacterial expression will ultimately have advantages over eukaryotic expression in terms of ease of use and quantity of materials obtained thereby.

It is proposed that transformation of host cells with DNA segments encoding VMP-like proteins will provide a convenient means for obtaining VMP-like peptides. Both cDNA and genomic sequences are suitable for eukaryotic expression, as the host cell will, of course, process the genomic transcripts to yield functional mRNA for translation into protein.

It is similarly believed that almost any eukaryotic expression system may be utilized for the expression of VMP-like proteins, e.g., baculovirus-based, glutamine synthase-based or dihydrofolate reductase-based systems could be employed. However, in preferred embodiments, it is contemplated that plasmid vectors incorporating an origin of replication and an efficient eukaryotic promoter, as exemplified by the eukaryotic vectors of the pCMV series, such as pCMV5, will be of most use.

For expression in this manner, one would position the coding sequences adjacent to and under the control of the promoter. It is understood in the art that to bring a coding sequence under the control of such a promoter, one positions the 5' end of the transcription initiation site of the transcriptional reading frame of the protein between about 1 and about 50 nucleotides "downstream" of (i.e., 3' of) the chosen promoter.

Where eukaryotic expression is contemplated, one will also typically desire to incorporate into the transcriptional unit which includes VMP-like protein, an appropriate polyadenylation site (e.g., 5'-AATAAAA-3') if one was not contained within the original cloned segment. Typically, the poly A addition site is placed about 30 to 2000 nucleotides "downstream" of the termination site of the protein at a position prior to transcription termination.

Translational enhancers may also be incorporated as part of the vector DNA. Thus the DNA constructs of the present invention should also preferable contain one or more 5' non-translated leader sequences which may serve to enhance expression of the gene products from the resulting mRNA transcripts. Such sequences may be derived from the promoter selected to express the gene or can be specifically modified to increase translation of the RNA. Such regions may also be obtained from viral RNAs, from suitable eukaryotic genes, or from a synthetic gene sequence.

Such "enhancer" sequences may be desirable to increase or alter the transcription of translational efficiency of the resultant mRNA. The present invention is not limited to constructs where the enhancer is derived from the native 5'-nontranslated promoter sequence, but may also include

non-translated leader sequences derived from other non-related promoters such as other enhancer transcriptional activators or genes.

It is contemplated that virtually any of the commonly employed host cells can be used in connection with the expression of VMPs in accordance herewith. Examples include cell lines typically employed for eukaryotic expression such as 239, AtT-20, HepG2, VERO, HeLa, CHO, WI 38, BHK, COS-7, RIN and MDCK cell lines.

It is contemplated that VMP-like protein may be “over-expressed”, i.e., expressed in increased levels relative to its natural expression in *Borrelia* cells, or even relative to the expression of other proteins in a recombinant host cell containing VMP-encoding DNA segments. Such overexpression may be assessed by a variety of methods, including radio-labeling and/or protein purification. However, simple and direct methods are preferred, for example, those involving SDS/PAGE and protein staining or Western blotting, followed by quantitative analyses, such as densitometric scanning of the resultant gel or blot. A specific increase in the level of the recombinant protein or peptide in comparison to the level in natural VMP-producing animal cells is indicative of overexpression, as is a relative abundance of the specific protein in relation to the other proteins produced by the host cell and, e.g., visible on a gel.

As used herein, the term “engineered” or “recombinant” cell is intended to refer to a cell into which a recombinant gene, such as a gene encoding a VMP-like peptide has been introduced. Therefore, engineered cells are distinguishable from naturally occurring cells which do not contain a recombinantly introduced gene. Engineered cells are thus cells having a gene or genes introduced through the hand of man. Recombinantly introduced genes will either be in the form of a cDNA gene (i.e., they will not contain introns), a copy of a genomic gene, or will include genes positioned adjacent to a promoter not naturally associated with the particular introduced gene.

It will be understood that recombinant VMP-like proteins may differ from naturally produced VMP-like proteins in certain ways. In particular, the degree of post-translational modifications, such as, for example, lipidation, glycosylation and phosphorylation may be different between the recombinant VMP-like and the VMP-like polypeptide purified from a natural source, such as *Borrelia*.

After identifying an appropriate DNA molecule by any or a combination of means as described above, the DNA may then be inserted into any one of the many vectors currently known in the art and transferred to a prokaryotic or eukaryotic host cell where it will direct the expression and production of the so-called “recombinant” version of the protein. The recombinant host cell may be selected from a group consisting of *S. mutans*, *E. coli*, *S. cerevisiae*, *Bacillus* sp., *Lactococci* sp., *Enterococci* sp., or *Salmonella* sp. In certain preferred embodiments, the recombinant host cell will have a recA phenotype.

Where the introduction of a recombinant version of one or more of the foregoing genes is required, it will be important to introduce the gene such that it is under the control of a promoter that effectively directs the expression of the gene in the cell type chosen for engineering. In general, one will desire to employ a promoter that allows constitutive (constant) expression of the gene of interest. The use of these constitutive promoters will ensure a high, constant level of expression of the introduced genes. The level of expression from the introduced genes of interest can vary in different clones, probably as a function of the site of insertion of the recombinant gene in the chromosomal DNA. Thus, the level

of expression of a particular recombinant gene can be chosen by evaluating different clones derived from each transfection study; once that line is chosen, the constitutive promoter ensures that the desired level of expression is permanently maintained. It may also be possible to use promoters that are subject to regulation, such as those regulated by the presence of lactose analog or by the expression of bacteriophage T7 DNA polymerase.

Technology for introduction of DNA into cells is well-known to those of skill in the art. Five general methods for delivering a gene into cells have been described: (1) chemical methods; (2) physical methods such as microinjection, electroporation and the gene gun; (3) viral vectors; (4) receptor-mediated mechanisms; and (5) direct injection of purified DNA into human or animals.

G. Liposomes and Nanocapsules

The formation and use of liposomes is generally known to those of skill in the art (see for example, Couvreur et al., *Pharm Res.*: 8(9), 1079-86, 1991, which describes the use of liposomes and nanocapsules in the targeted antibiotic therapy of intracellular bacterial infections and diseases). Recently, liposomes were developed with improved serum stability and circulation half-times of substances, including DNA (Gabizon and Papahadjopoulos, *Proc Natl Acad Sci USA.*, 85(18): 6949-53, 1988; Allen and Chonn, *FEBS Lett.*, 223(1): 42-6, 1987). The following is a brief description of this and other DNA delivery modes.

Nanocapsules can generally entrap compounds in a stable and reproducible way (Henry-Michelland et al., *Int J Pharm.*, 35: 121-127, 1987). To avoid side effects due to intracellular polymeric overloading, such ultrafine particles (sized around 0.1 μm) should be designed using polymers able to be degraded in vivo. Biodegradable polyalkyl-cyanoacrylate nanoparticles that meet these requirements are contemplated for use in the present invention, and such particles may be easily made, as described (Couvreur, *J. Pharm Belg.*, 39(4): 249-54, 1984; Couvreur et al., *Bull Mem Acad R Med Belg.*, 143(7-9): 378-88, 1988).

Liposomes are formed from phospholipids that are dispersed in an aqueous medium and spontaneously form multilamellar concentric bilayer vesicles (also termed multilamellar vesicles (MLVs)). MLVs generally have diameters ranging from 25 μm to 4 μm . Sonication of MLVs results in the formation of small unilamellar vesicles (SUVs) with diameters in the range of 200 to 500 \AA , containing an aqueous solution in the core.

The following information may be utilized in generating liposomal formulations. Phospholipids can form a variety of structures other than liposomes when dispersed in water, depending on the molar ratio of lipid to water. At low ratios the liposome is the preferred structure. The physical characteristics of liposomes depend on pH, ionic strength and the presence of divalent cations. Liposomes can show low permeability to ionic and polar substances, but at elevated temperatures undergo a phase transition which markedly alters their permeability. The phase transition involves a change from a closely packed, ordered structure, known as the gel state, to a loosely packed, less-ordered structure, known as the fluid state. This occurs at a characteristic phase-transition temperature and results in an increase in permeability to ions, sugars and drugs.

Liposomes interact with cells via four different mechanisms: Endocytosis by phagocytic cells of the reticuloendothelial system such as macrophages and neutrophils; adsorption to the cell surface, either by nonspecific weak hydrophobic or electrostatic forces, or by specific interactions with cell-surface components; fusion with the plasma

cell membrane by insertion of the lipid bilayer of the liposome into the plasma membrane, with simultaneous release of liposomal contents into the cytoplasm; and by transfer of liposomal lipids to cellular or subcellular membranes, or vice versa, without any association of the liposome contents. It often is difficult to determine which mechanism is operative and more than one may operate at the same time.

L. Pharmaceutical Compositions

The pharmaceutical compositions disclosed herein may be orally administered, for example, with an inert diluent or with an assimilable edible carrier, or they may be enclosed in hard or soft shell gelatin capsule, or they may be compressed into tablets, or they may be incorporated directly with the food of the diet. For oral therapeutic administration, the active compounds may be incorporated with excipients and used in the form of ingestible tablets, buccal tables, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. Such compositions and preparations should contain at least 0.1% of active compound. The percentage of the compositions and preparations may, of course, be varied and may conveniently be between about 2 to about 60% of the weight of the unit. The amount of active compounds in such therapeutically useful compositions is such that a suitable dosage will be obtained.

The tablets, troches, pills, capsules and the like may also contain the following: a binder, as gum tragacanth, acacia, cornstarch, or gelatin; excipients, such as dicalcium phosphate; a disintegrating agent, such as corn starch, potato starch, alginic acid and the like; a lubricant, such as magnesium stearate; and a sweetening agent, such as sucrose, lactose or saccharin may be added or a flavoring agent, such as peppermint, oil of wintergreen, or cherry flavoring. When the dosage unit form is a capsule, it may contain, in addition to materials of the above type, a liquid carrier. Various other materials may be present as coatings or to otherwise modify the physical form of the dosage unit. For instance, tablets, pills, or capsules may be coated with shellac, sugar or both. A syrup or elixir may contain the active compounds sucrose as a sweetening agent methyl and propylparabens as preservatives, a dye and flavoring, such as cherry or orange flavor. Of course, any material used in preparing any dosage unit form should be pharmaceutically pure and substantially non-toxic in the amounts employed. In addition, the active compounds may be incorporated into sustained-release preparation and formulations.

The active compounds may also be administered parenterally or intraperitoneally. Solutions of the active compounds as free base or pharmacologically acceptable salts can be prepared in water suitably mixed with a surfactant, such as hydroxypropylcellulose. Dispersions can also be prepared in glycerol, liquid polyethylene glycols, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations contain a preservative to prevent the growth of microorganisms.

The pharmaceutical forms suitable for injectable use include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. In all cases the form must be sterile and must be fluid to the extent that easy syringability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms, such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils.

The proper fluidity can be maintained, for example, by the use of a coating, such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. The prevention of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating the active compounds in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum-drying and freeze-drying techniques which yield a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

As used herein, "pharmaceutically acceptable carrier" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents and the like. The use of such media and agents for pharmaceutical active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active ingredient, its use in the therapeutic compositions is contemplated. Supplementary active ingredients can also be incorporated into the compositions.

The phrase "pharmaceutically acceptable" refers to molecular entities and compositions that do not produce an allergic or similar untoward reaction when administered to a human. The preparation of an aqueous composition that contains a protein as an active ingredient is well understood in the art. Typically, such compositions are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid prior to injection can also be prepared. The preparation can also be emulsified.

The composition can be formulated in a neutral or salt form. Pharmaceutically acceptable salts, include the acid addition salts (formed with the free amino groups of the protein) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups can also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, histidine, procaine and the like.

Upon formulation, solutions will be administered in a manner compatible with the dosage formulation and in such amount as is therapeutically effective. The formulations are easily administered in a variety of dosage forms such as injectable solutions, drug release capsules and the like.

For parenteral administration in an aqueous solution, for example, the solution should be suitably buffered if necessary and the liquid diluent first rendered isotonic with sufficient saline or glucose. These particular aqueous solutions are especially suitable for intravenous, intramuscular, subcutaneous and intraperitoneal administration. In this con-

nection, sterile aqueous media which can be employed will be known to those of skill in the art in light of the present disclosure. For example, one dosage could be dissolved in 1 ml of isotonic NaCl solution and either added to 1000 ml of hypodermoclysis fluid or injected at the proposed site of infusion, (see for example, "Remington's Pharmaceutical Sciences" 15th Edition, pages 1035-1038 and 1570-1580). Some variation in dosage will necessarily occur depending on the condition of the subject being treated. The person responsible for administration will, in any event, determine the appropriate dose for the individual subject. Moreover, for human administration, preparations should meet sterility, pyrogenicity, general safety and purity standards as required by FDA Office of Biologics standards.

EXAMPLES

The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

Example 1

Experimental Procedures

Bacterial Strains

B. garinii Ip90 was initially isolated from ticks collected in eastern Russia (Kriuchechnikov et al., 1988). *B. afzelii* ACAI was cultured from a patient in Sweden with acrodermatitis chronica atrophicans (Asbrink et al., 1984). Both strains were graciously provided by Dr. Alan Barbour, University of California at Irvine School of Medicine, and had been passed through C3H/HeN mice to assure infectivity. Strains were passaged in vitro fewer than 5 times following mouse infection.

DNA Cloning and Sequencing

Plasmid DNA was purified from the *Borrelia* strains as described previously (Purser and Norris, 2000). λ DASH II libraries of plasmid DNA fragments were prepared as described by Zhang et al. (Zhang et al., 1997), with minor modifications. Thirty micrograms of plasmid DNA was treated with 30 units of mung bean nuclease at 30° C. for 30 min to hydrolyze hairpin loops in telomeres, and an EcoRI linker (5'-CCGGAATTCCGG-3'; SEQ. ID. NO:107) was then ligated to the treated plasmid DNA using T₄ DNA ligase at 15° C. overnight. This preparation was then digested to completion with EcoRI, and the resulting DNA fragments were fractionated by agarose gel electrophoresis. EcoRI-treated DNA fragments ranging in size from 8 kb to 25 kb were used to create libraries in EcoRI pre-treated λ DASH II vector arms as described in the manufacturer's instructions (Stratagene, La Jolla, Calif., USA). Recombinant phages were screened by plaque hybridization using *B. burgdorferi* B31 vls silent cassette clone pJRZ53 (Zhang et al., 1997) as probe; hybridization with pJRZ53 was confirmed by secondary phage plaque screening as well as Southern blot hybridization. Selected phage clones were expanded, phage were purified, and DNA was prepared by

standard techniques. The λ phage clones Ip90.1A1 and ACAI.2A1, each containing a 15 kb *borrelia* DNA insert, were selected for analysis.

To sequence the DNA insert of Ip90.1A1, the phage DNA was digested with EcoRI and HindIII and a 6 kb EcoRI/HindIII fragment containing vls-like sequence was then cloned into pBluescript II SK(-) (Stratagene). The plasmid DNA of the pBluescript clone was digested with EcoRI and HindIII, and the 6 kb DNA fragment was isolated by agarose gel electrophoresis followed by electroelution, partially digested with DNase I and cloned into EcoRV treated pBluescript II SK (-) to create random DNase I library as described previously (Zhang et al., 1997). Clones with insert DNA ranging in size from 500 to 1,000 bp from the DNase I library were selected for sequencing using primers specific for the vector T7 and T3 sequences. To facilitate sequencing of the ACAI.2A1 clone, the phage DNA was treated with XbaI and EcoRI, and one 8 kb EcoRI/XbaI fragment containing vls-like sequence was isolated from an agarose gel. This 8 kb EcoRI/XbaI fragment was digested separately with RsaI and PstI and then cloned into pBluescript II SK (-) to generate RsaI and PstI libraries. Clones from both libraries were selected for sequencing at the Department of Microbiology and Molecular Genetics Sequencing Facility. Primer walking and PCR (see below) were utilized as needed to fill gaps, establish clone order, and confirm and extend the sequences. DNA sequences were assembled using DNASTAR software (DNASTAR, Inc., Madison, Wis.).

Southern Hybridization

Fifty nanograms of DNA was digested with the indicated restriction enzymes, subjected to agarose electrophoresis in 1×TAE buffer at 100V for 2 hr, and transferred to Amersham Hybond N⁺ membranes using standard alkaline transfer techniques. Hybridization with pJRZ53 as probe was performed by enhanced chemiluminescence techniques following the manufacturer's protocol (Amersham Gene Images, Amersham, Piscataway, N.J., USA).

PCR and RT-PCR

PCR was utilized to amplify vls sequences beyond the end of the 8 kb EcoRI/XbaI fragment from ACAI, and thereby extend the sequence beyond the cloned region. The specific primer 4540 (5'-CCA GCA AAC AAC TTC CCC GCC-3'—SEQ ID NO:21), based on a variable region, and the nonspecific primer 4548 (5'-ATC CTT AAA CTC CGC CCC ATC ATC-3'—SEQ ID NO:22), based on an invariant 5' region of the vls silent cassettes of ACAI, were used as primers. Primer 4545 (5'-GAG TGC TGT GGA GAG TGC TGT TGA TGA G-3'—SEQ ID NO:23), based on the direct repeat sequence, was also used in some PCR studies. *B. afzelii* ACAI plasmid DNA was used as the template in these reactions.

RT-PCR was used to detect transcription of vlsE in *B. garinii* Ip90 and *B. afzelii* ACAI. Forward primer 4587 (5'-GGG GAT AAA GGG GAT TGT TGAT GCT GC-3'—SEQ ID NO:24) and reverse primer 4588 (5'-GCA AAC TGC CCA TCC TTA GCC ATT CC-3'—SEQ ID NO:25) were designed based on the invariable regions of vls silent cassettes of Ip90; the forward primer 4470 (5'-AAG GGG ATT GCG AAG GGG ATA AAG G-3'—SEQ ID NO:26) and reverse primer 4471 (5'-TTA GCA GCA AACTTT CCA TCC TTA GCC-3'—SEQ ID NO:27) were used for ACAI. Total RNA was isolated from late log-phase cultures of Ip90 and ACAI using an RNA purification kit (Amersham). RT-PCR was carried out using the Promega Access RT-PCR kit according to manufacturer's instructions. Briefly, reverse transcription was carried out for 50 min at 48° C. followed

by an initial denaturation at 94° C. for 3 min, and 30 cycles consisting of denaturation at 94° C. for 30 sec, annealing at 68° C. for 1.5 min, and extension at 68° C. for 1.5 min.

Cloning and Sequencing vlsE RT-PCR Products

As mentioned above, both *B. afzelii* ACAI and *B. garinii* Ip90 used in these studies were first cloned by colony formation and then passaged through mice. To determine whether vlsE sequence variation was present following mouse infection, *B. afzelii* ACAI was grown from a frozen stock and cloned by colony formation on BSKY plates (Dever et al., 1992). RT-PCR of individual clones was performed as described in a previous section, and cDNA was ligated into pCR 2.1 TOPO TA cloning vector (Invitrogen, Carlsbad, Calif., USA). Each vlsE variant was sequenced with the M13 forward and reverse primers. *B. garinii* Ip90 RNA was isolated from an uncloned population following mouse infection, and thus contained a mixture of variants. RT-PCR and cDNA cloning were performed using the method described for ACAI. Sequences were aligned with the multiple alignment program (Smith et al., 1996). The alignment output was formatted using Boxshade 3.21 (Hofmann and Baron, 1996).

Accession Numbers

The sequence of the vls silent cassette region of *B. afzelii* ACAI is provided at the United States National Center for Biomedical Information with GenBank accession number AY100628 (SEQ ID: NO:57). The *B. garinii* Ip90 silent cassette region is listed as AY100633 (SEQ ID NO:28). The RT-PCR product sequences obtained are listed as AY100629-AY100632 (SEQ ID: NOS:5-12) and AY100634-AY100637 (SEQ ID NOS:13-20) for ACAI and Ip90, respectively.

Example 2

Identification of Vls Loci in *B. garinii* Ip90 and *B. afzelii* ACAI

Hybridization with the *B. burgdorferi* B31 vls silent cassette sequence in recombinant plasmid pJRZ53 was used as a means of identifying the plasmids and DNA fragments containing vls sequences in *B. garinii* Ip90 and *B. afzelii* ACAI. The pJRZ53 probe hybridized exclusively to plasmids with an approximate size of 28 kb in both ACAI and Ip90. Following treatment of plasmid preparations with restriction enzymes, the major hybridizing DNA segments were identified as a 15 kb EcoRI fragment of ACAI DNA and a 20 kb EcoRI fragment of Ip90 plasmid DNA. Libraries of plasmid DNA EcoRI fragments were prepared in Lambda Dash II using a technique that permits the cloning of telomere-containing as well as internal fragments through treatment of the hairpin loop telomeres with mung bean nuclease followed by ligation with EcoRI linkers (Zhang et al., 1997). The phage libraries were screened by hybridization with pJRZ53, and clones Ip90.1A1 and ACAI.2A1, each containing 15 kb of insert DNA, were used for further analysis.

Example 3

Organization of Vls Silent Cassette Loci

The overall organization of the vls silent cassette loci of Ip90 and ACAI is shown in FIG. 1. As was the case in *B. burgdorferi* B31, the silent cassette loci in each strain was composed of a contiguous array of multiple cassettes. The loci in Ip90 and ACAI consisted largely of contiguous,

uninterrupted open reading frames, with one frameshift present at the 3' end of cassette 9 in ACAI. The B31 vls silent cassette locus contained one stop codon and two frame shifts (Zhang et al., 1997).

Example 4

Structure of the Ip90 Vls Silent Cassette Locus

In Ip90, the vls array consisted of 11 regions with homology to the vls cassettes of B31 (FIG. 1A). With the exception of the junctions at vls3/4 and vls6/7, the 11 vls silent cassettes are flanked by 18 bp direct repeat sequences in the 6 kb region. However, several of these cassettes (vls1, vls4, vls6, and vls11) were truncated (189 to 288 bp in length) relative to the other, full-length cassettes ranging in size from 573 to 594 bp. By comparison with the vls expression cassette of B31, cassette 1 is truncated at the 3' region, containing only 92 amino acid codons; cassette 4 lacks 125 codons in its 5' region; cassette 6 contains only 89 codons and is missing most of the 3' region; and cassette 11 has 86 codons, but is missing the 3' region. A portion of the silent cassette locus from the last 3 bp of cassette 5 to the first 165 bp of cassette 8 is identical to the P7-1 clone previously characterized by Liang et al. (Liang and Philipp, 1999) (FIG. 1A). The 3' end of the Ip90 silent cassette locus possessed a truncated pseudogene of a conserved hypothetical protein belonging to gene family 144 of *B. burgdorferi* B31 (TIGR, 2002).

The 5' end of the locus also contained a region homologous to the 5', unique (non-cassette) portion of B31 expression site, vlsE (FIG. 1A). However, this gene segment is lacking a promoter region and the first 59 codons of vlsE, and also contains segments that are non-homologous to B31 vlsE. Therefore, this 'vlsE-like' sequence appears to be a pseudogene, although it is in frame with the cassette 1 of the vls silent cassette array and could conceivably encode a vlsE-like product. It is of interest to note that vlsE of *B. burgdorferi* B31 is located close to the telomere of Ip28-1, but is oriented in the opposite direction (i.e. is transcribed toward the telomere) relative to the vlsE-like sequence of Ip90. In addition, the reading frame of the vls silent cassette array in Ip90 runs away from, rather than toward (as is the case with the silent cassettes in B31), the nearest telomere (FIG. 1) (Zhang et al., 1997). Therefore, the B31 and Ip90 versions of the silent cassette loci have likely undergone large-scale rearrangements during evolution from a common ancestral organism, and it is unlikely that the Ip90 vlsE-like pseudogene evolved directly from a functional telomeric copy of vlsE. Based on other evidence, we believe that a functional vlsE gene is located elsewhere on the 28 kb plasmid of Ip90 (see below).

Portions of several vls silent cassettes from *Borrelia garinii* strain A87S were published previously (Wang et al., 2001). Each putative silent cassette in the longest available A87S sequence (GenBank Accession No. AF274070) was compared to its corresponding cassette among the Ip90 silent cassettes. The A87S sequence shared only 63 to 68% nucleotide identity to Ip90 sequences, and amino acid similarity ranged from 51 to 57%. An amino acid alignment between the A87S and Ip90 silent cassettes reveals that the heterogeneity exists largely within invariable region 1 (IR1), found upstream of VR-I (data not shown). There are also considerable differences in IR4 and IR6, but to a lesser extent when compared to IR1. The sequence differences between the vls silent cassettes sequences of Ip90 and A87S indicates that a considerable degree of heterogeneity exists

43

among vls sequences within this species, as also appears to be the case with *Borrelia burgdorferi* strains.

An unusual feature of the Ip90 telomere region upstream of the vls cassettes is the presence of a set of 6 complete and 1 partial copies of a 41 bp direct repeat sequence. The telomere itself was identified by its location in the lambda clone insert next to the EcoRI linker used to clone mung bean nuclease-treated telomere regions. Because mung bean nuclease potentially could remove terminal nucleotides as well as disrupting the hairpin loop 5'-3' bond, it is not known whether this sequence represents the absolute end of the telomere sequence. The telomeric repeat sequences (TRS) begin 52 bp from the end of the telomere sequence, and are present as six 41-bp repeats (TRS-A through TRS-F) followed by a 32-bp truncated version of the 41-bp sequence (TRS-G) in a contiguous array. These direct repeats differ at only one position in TRS-B, and are otherwise identical. The telomeric direct repeat has no significant homology with vls sequences or any other *borrelia* sequence reported previously. Although the direct repeats obviously arose through duplication events, their origin and significance are unknown at this time.

Example 5

Structure of the ACAI Vls Silent Cassette Locus

The overall arrangement of the *B. afzelii* ACAI vls silent cassette locus is depicted in FIG. 1B. Unlike Ip90 and B31, the ACAI vls locus was located on an internal EcoRI fragment of a 28-kb linear plasmid, and its location relative to the plasmid telomeres is not known. The ACAI vls locus contains 13 complete and 1 partial silent cassettes and each cassette is also flanked by an 18 bp direct repeat sequence. Twelve of the cassettes appear to represent 'full-length' sequences (ranging from 591 to 630 bp in length), whereas cassette 11 contains an internal deletion and cassette 14 has an internal deletion and a short, 3' truncation relative to the other cassette sequences (FIG. 1B). The 3' end of the silent cassette locus is demarcated by a complete copy of a conserved hypothetical protein gene belonging to gene family 57 of *B. burgdorferi* B31 (TIGR, 2002). We were unable to obtain additional sequence 5' of cassette 1, and it is possible that additional vls sequences are localized upstream of the region we have characterized thus far.

Example 6

Direct Repeats in the Silent Cassette Loci

In *B. burgdorferi* B31, both the central cassette of vlsE and the homologous vls silent cassettes are flanked by a 17 bp direct repeat sequence (5'-TGAGGGGGCTATTAAGG-3' (SEQ ID NO:106)). This sequence is generally well-conserved in the vlsE expression site and the silent cassettes; it is absent from the 5'-truncated cassette 1, and only 10 of 17 nucleotides are present at the junction between vls9 and vls10 (Zhang et al., 1997). Based on the location and high degree of conservation of the 17 bp direct repeat, it was hypothesized previously that these sequences may play an important role in the vls gene conversion process. However, the 17 bp sequence is not highly conserved in the *B. garinii* Ip90 and *B. afzelii* ACAI vls silent cassette sequences (data not shown). A comparison of 17 bp consensus sequences from Ip90 and ACAI to the B31 17 bp sequence shows that the Ip90 and ACAI sequences are more similar to each other than to the B31 sequence. Nevertheless, the higher degree of

44

variability in the Ip90 and ACAI 17 bp sequences compared to the B31 sequence suggests that the 17 bp sequence is not as important in the gene conversion process as previously thought (Zhang et al., 1997).

Example 7

Similarity of Vls Silent Cassette Loci

Alignment of the vls cassette sequences from Ip90, ACAI, and B31 indicates a high degree of sequence conservation both within and between each strain (FIG. 2). The Ip90 cassettes share 90 to 97% nucleotide sequence identity with one another, whereas the ACAI silent cassettes have from 84 to 91% nucleotide sequence identity (data not shown). The Ip90 vls silent cassettes are also highly homologous with *B. burgdorferi* vls sequences; for example, sequence identities with the B31 allele vlsE1 (Zhang et al., 1997) range from 64% to 73% on the nucleotide level and from 53% to 62% in predicted amino acid sequence (FIG. 2A). The identities between the ACAI vls silent cassettes and B31 vlsE1 likewise range from 65% to 73% on the nucleotide level and from 50% to 65% in predicted amino acid sequence (FIG. 2B). Each complete silent cassette of Ip90 and ACAI contains six variable regions interspersed by six invariable regions similar to those found in the vls sequences of B31 (FIG. 2).

SEQ ID NO:28 is the *B. garinii* Ip90 vls locus silent cassette nucleic acid sequence. SEQ ID NO:30 is a translation of an upstream open reading frame of SEQ ID NO:28, which is contiguous with the open reading frame of the silent cassettes of the *B. garinii* Ip90 vls locus. SEQ ID NO:32 is a translation of a vlsE-like sequence of SEQ ID NO:28. SEQ ID NOS:33-54 are nucleotide and amino acid sequences of silent cassette Nos. 1-11 of the *B. garinii* Ip90 vls locus as set forth in FIG. 2B. SEQ ID NO:55 and 56 are the nucleotide and amino acid sequences of a truncated pseudogene in the *B. garinii* Ip90 vls locus with 85% similarity to amino acids 70-140 of the *B. burgdorferi* B31 ORF-10 predicted product, GenBank Accession No. AA 34908.

SEQ ID NO:57 is the *B. afzelii* ACAI vls silent cassette locus nucleic acid sequence. SEQ ID NOS:58-85 are the nucleotide and amino acid sequences of silent cassette Nos. 1-14 of the *B. afzelii* ACAI silent cassette locus as set forth in FIG. 2A. SEQ ID NOS:86 and 87 are the nucleotide and amino acid sequences of a portion of the *B. afzelii* ACAI vls silent cassette locus which encodes a member of protein family PF02414, a conserved hypothetical protein family thought to be involved in *Borrelia* plasmid partitions of replication.

Example 8

Transcription of vlsE of *B. garinii* Ip90 and *B. afzelii* ACAI

We have thus far been unsuccessful in cloning a complete vlsE expression site from either Ip90 or ACAI using a variety of approaches (data not shown). To determine whether vls expression sites are present in Ip90 and ACAI, RT-PCR was carried out using total RNA from in vitro cultured *B. garinii* Ip90 and *B. afzelii* ACAI. Primers corresponding to invariant regions in the vls silent cassette regions of each organism were utilized. We observed a positive RT-PCR result in ethidium bromide-stained agarose gels for both *B. garinii* Ip90 and *B. afzelii* ACAI, but no products were observed if reverse transcriptase was omitted

in the RT reaction (FIG. 3). The RT-PCR products containing vls-like sequence were confirmed by sequencing, confirming that both organisms have vls expression sites. In *B. burgdorferi* B31, vlsE is located only 160 bp from the vls silent cassette array (Hudson et al., 2001; Zhang et al., 1997). Based on our studies, the vls expression sites of ACAI and Ip90 do not appear to be located in close proximity to the vls silent cassettes.

Example 9

Sequence Analysis of vlsE Variants of *B. afzelii* ACAI and *B. garinii* Ip90

Both ACAI and Ip90 were passaged through mice prior to analysis. In previous studies with *B. burgdorferi* B31, extensive sequence variation due to apparent gene conversion events occurred within the vlsE cassette region during mouse infection (Zhang and Norris, 1998a, b). To determine whether similar sequence variation occurred in ACAI and Ip90, individual RT-PCR products from each mouse-passaged strain were cloned and sequenced.

An alignment of the predicted VlsE protein sequences of ACAI and Ip90 (FIG. 4) demonstrated that sequence variation occurred within each strain. Moreover, the changes observed were consistent with gene conversion involving segments of the silent cassettes, as had been seen previously with B31. As with B31, the sequence differences were predictably localized primarily within the variable regions.

Using the sequences from the silent cassettes of each organism (FIG. 2), we determined the silent cassette sequences that were most likely involved in the gene conversion events within ACAI and Ip90 vlsE genes (FIG. 4). The theoretical minimum and maximum recombination events are indicated by solid and dotted lines, respectively. In FIG. 4A, silent cassette amino acid sequences matching regions of each variant are noted for all ACAI vlsE variants except clone 2622. The variation seen in clones 2624a and 2624b can be attributed to two silent cassettes each. In clone 2624a, vls8 matched the sequence found in a portion of variable region I (VR-I) and the entire sequence within VR-II, while vls7 matched the sequence found in VR-III, VR-IV, and VR-V. In clone 2624b, vls10 matched the sequence found in a portion of VR-I and the entire sequence within VR-II and VR-III, while vls12 matched the sequence found in VR-IV and VR-V. While both vls5 and vls6 match large portions of sequence in clone 2625, it seems more likely that vls5 was exclusively involved in the gene conversion events leading to the variation seen in clone 2625 since it contains sequence identity to VR-II, VR-III, VR-IV, and VR-V. It was difficult to ascertain which silent cassettes most likely contributed to the variation seen in clone 2622. Most silent cassettes matches spanned only a few residues in clone 2622. The nature of the sequence in clone 2622 suggests that it may be an artifactual PCR product.

Minimal recombination regions, indicated by solid lines in FIG. 4, were defined as the range of a vlsE RT-PCR product sequence that matched only a single silent cassette sequence. These commonly extend over several variable regions, as was also the case with *B. burgdorferi* B31 in previous studies (Zhang et al., 1997). In some cases, there are two or more silent cassettes that contain the same sequence within the same range. Therefore, it is only possible to predict the most likely silent cassette sequences involved (Indest et al., 2001). Maximum recombination regions commonly extend from a variable region and continue into the flanking invariant region of the corresponding

matching silent cassette (FIG. 4). The extension of the maximum recombination region ends at the first position of sequence non-identity between the vlsE sequence of the clone and the given silent cassette. The degree of variation appears to be less than observed previously with *B. burgdorferi* B31, but an analysis of vlsE at different times during mammalian infection (Zhang and Norris, 1998b) is required to provide an accurate measure of the kinetics.

There are two instances of what we believe to be point mutations in the Ip90 clones (FIG. 4B). The first instance lies two residues upstream of VR-II in clone 21, where there is an arginine residue not encoded in the silent cassettes. We believe a point mutation was responsible for changing the AAG codon in the silent cassettes to AGG in clone 21. The second example of a possible point mutation is the lone threonine after VR-V in clone 20. All of the silent cassette sequences possess a GCT codon at that position, while ACT is present in clone 20.

In conclusion, our results verify previous indications that both *B. garinii* and *B. afzelii* contain plasmid-encoded vls silent cassette loci similar to those of *B. burgdorferi*. In addition, RT-PCR results indicate that a vls product is expressed by both species, and that sequence variation occurs and hence may contribute to antigenic variation. Taken together, these and previous findings confirm that the vls sequence variation system is a common feature of Lyme disease *borrelia*, and hence is likely to be important in the pathogenesis of these organisms.

Example 10

Reactivity of Sera from Human Lyme Disease Patients and Infected Mice with *Borrelia afzelii* Protein

A recombinant DNA vector comprising a nucleotide sequence encoding the predicted amino acid sequence of the *B. afzelii* ACA-I vls cassette 13 (SEQ ID NOs:96 and 97) has been constructed. Briefly, DNA containing the coding sequence of the cassette region was amplified using a two-step polymerase chain reaction (PCR) method. During the first amplification, specific primers flanking the *B. afzelii* ACA-1 vls cassette (5'-CGGAATTC~~ACT~~CGCCTTACTAT-TATC-3' (SEQ ID NO:98) and 5'-CGGGATCCGAGAGT-GCTGTTGATGAGGTT-3' (SEQ ID NO:99)) were used with *B. afzelii* ACA-I DNA as template to amplify a fragment containing the desired cassette. Then a second PCR was performed using primers specific for the cassette region itself (5'-CGGGATCC~~CAAGAGT~~GCTGTGGATGAGGCT-AGCAAG-3' (SEQ ID NO:100) and 5'-TTCTGCAGCACACTCGCCTTACTATTATCATTAGC-3' (SEQ ID NO:101)) and the purified product of the first reaction as the DNA template. The two primers contained BamHI and PstI sites, respectively (underlined); the PCR product was treated with these two enzymes and ligated into the expression vector pQE30 cut with the same two enzymes. The sequence of the insert was analyzed and found to be the correct sequence. The resulting recombinant plasmid, pBA-13-1 was used to transform *E. coli* cells, and expression was induced by incubation of a transformed *E. coli* clone to 1 mM isopropyl-β-D-thiogalactopyranoside (IPTG) for 3 hours. The *E. coli* cells were lysed by sonication and centrifuged to remove cellular debris. The recombinant, His6-tagged protein (VLS-BA13) was purified by liquid chromatography over a nickel affinity column, elution of bound protein with imidazole, and further purification

using a heparin-Sepharose column. The purity of the protein was determined to be >90% by sodium-dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), and the concentration determined by a Bradford protein assay.

The purified recombinant protein VLS-BA13 was tested for reactivity with antibodies from humans using a pool of sera from patients fulfilling CDC criteria for Lyme disease, acquired in the North Central United States. A pool of negative control sera was obtained from human blood donors in Houston, Tex. Enzyme-linked immunosorbent assays (ELISAs) were performed as described (Lawrenz et al., *J. Clin. Microbiol.*, 37(12): 3997-4004, 1999), except that protein and serum concentrations were varied to determine the optimal concentrations. As shown in FIG. 6, VLS-BA13 protein (50 nanograms per well) consistently yielded higher absorbance readings with the Lyme disease serum pool than with the normal serum pool, up to a serum dilution of 1:6400. Differences in absorbance between the two serum preparations (1:200 dilution) were observed with VLS-BA13 protein concentrations as low as 3.13 nanograms per well (FIG. 7). Very similar results were obtained with sera from mice infected experimentally with *Borrelia burgdorferi* and sera from uninfected mice (FIGS. C and D). Taken together, these results provide evidence that amino acid sequences corresponding to *B. afzelii* Vls protein sequences react in a specific and sensitive manner with serum antibodies from Lyme disease patients or from *B. burgdorferi* infected mice.

Example 11

Reactivity of Sera from Human Lyme Disease Patients and Infected Mice with *Borrelia garinii* Protein

A recombinant DNA vector comprising a nucleotide sequence encoding the predicted amino acid sequence of the *B. garinii* Ip90 vls cassette 10 (SEQ ID NOs:94 and 95) has been constructed. Briefly, DNA containing the coding sequence of the cassette region was amplified using a two-step polymerase chain reaction (PCR) method. During the first amplification, specific primers flanking the *B. garinii* Ip90 vls cassette 10 (5'-CGGGATCCGCTGT-TGGGAGTYGCAAC-3' (SEQ ID NO:102) and 5'-AACTGCAGATTATCATGAGCAGCATCCTTC-3' (SEQ ID NO:103)) were used with *B. garinii* Ip90 DNA as template to amplify a fragment containing the desired cassette. Then a second PCR was performed using primers specific for the cassette region itself (5'-CGGGATCCAAGGGGACTGT-TAAGAATGCTGTTG-3' (SEQ ID NO:104) and 5'-TTCTGCAGATGATTATCATGAGCAGCATCCTTCA-3'(SEQ ID NO:105)) and the purified product of the first reaction as the DNA template. The two primers contained BamHI and PstI sites, respectively (underlined); the PCR product was treated with these two enzymes and ligated into the expression vector pQE30 cut with the same two enzymes. The sequence of the insert was analyzed and found to be the correct sequence. The resulting recombinant plasmid, pBG-10-1 was used to transform *E. coli* cells, and expression was induced by incubation of a transformed *E. coli* clone to 1 mM isopropyl-β-D-thiogalactopyranoside (IPTG) for 3 hours. The *E. coli* cells were lysed by sonication and centrifuged to remove cellular debris. The recombinant, His6-tagged protein (VLS-BG10) was purified by liquid chromatography over a nickel affinity column, elution of bound protein with imidazole, and further purification using a heparin-Sepharose column. The purity of the protein

was determined to be >90% by sodium-dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), and the concentration determined by a Bradford protein assay.

The purified recombinant protein VLS-BG10 was tested for reactivity with antibodies from humans using a pool of sera from patients fulfilling CDC criteria for Lyme disease, acquired in the North Central United States. A pool of negative control sera was obtained from human blood donors in Houston, Tex. Enzyme-linked immunosorbent assays (ELISAs) were performed as described (Lawrenz et al., *J. Clin. Microbiol.*, 37(12): 3997-4004, 1999), except that protein and serum concentrations were varied to determine the optimal concentrations. In the examples shown, the antigen (VLS-BG10) was used to coat the wells, and the measured parameter was the amount of antibody bound as determined by addition of either goat anti-human IgG (alkaline phosphatase conjugate) or goat anti-mouse IgG (alkaline phosphatase conjugate), followed by washing and addition of a suitable substrate. As shown in FIG. 10, VLS-BG10 protein (10 nanograms per well) consistently yielded higher absorbance readings with the Lyme disease serum pool than with the normal serum pool, up to a serum dilution of 1:6400. Differences in absorbance between the two serum preparations (1:200 dilution) were observed with VLS-BG10 protein concentrations as low as 0.031 micrograms per well (FIG. 11). Very similar results were obtained with sera from mice infected experimentally with *Borrelia burgdorferi* and sera from uninfected mice (FIGS. 12 and 13). Taken together, these results provide evidence that amino acid sequences corresponding to *B. garinii* Vls protein sequences react in a specific and sensitive manner with serum antibodies from Lyme disease patients or from *B. burgdorferi* infected mice.

All of the compositions and/or methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and/or methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

REFERENCES

The following references, to the extent that they provide exemplary procedural or other details supplementary to those set forth herein, are specifically incorporated herein by reference.

U.S. Pat. No. 3,791,932
 U.S. Pat. No. 3,949,064
 U.S. Pat. No. 4,174,384
 U.S. Pat. No. 4,196,265
 U.S. Pat. No. 4,518,584
 U.S. Pat. No. 4,554,101
 U.S. Pat. No. 4,578,770
 U.S. Pat. No. 4,596,792
 U.S. Pat. No. 4,599,230
 U.S. Pat. No. 4,599,231
 U.S. Pat. No. 4,601,903

U.S. Pat. No. 4,608,251
 U.S. Pat. No. 4,683,195
 U.S. Pat. No. 4,683,202
 U.S. Pat. No. 5,155,022
 U.S. Pat. No. 5,168,050
 U.S. Pat. No. 5,178,859
 U.S. Pat. No. 5,187,065
 U.S. Pat. No. 5,217,872
 U.S. Pat. No. 5,246,844
 U.S. Pat. No. 5,279,938
 U.S. Pat. No. 5,283,175
 U.S. Pat. No. 5,324,630
 U.S. Pat. No. 5,385,826
 U.S. Pat. No. 5,403,718
 U.S. Pat. No. 5,434,077
 U.S. Pat. No. 5,436,000
 U.S. Pat. No. 6,437,116
 Altschul, Gish, Miller, Myers, Lipman, "Basic local alignment search tool," *J. Mol. Biol.*, 215:403-410, 1990.
 Asbrink, Hederstedt, Hovmark, "The spirochetal etiology of erythema chronicum migrans Afzelius," *Acta Derm. Venerol.*, 64:291-295, 1984.
 Balmelii and Piffatetti, "Analysis of the genetic polymorphism of *Borrelia burgdorferi* sensu lato by multilocus enzyme electrophoresis," *Int. J. Syst. Bacteriol.*, 46:167-172, 1996.
 Barbour, "Plasmid analysis of *Borrelia burgdorferi*, the Lyme disease agent," *J. Clin. Microbiol.*, 42:475-478, 1988.
 Barbour, "Plasmid analysis of *Borrelia burgdorferi*, the Lyme disease agent," *J. Clin. Microbiol.*, 26:475-478, 1988.
 Barbour, "Linear DNA of *Borrelia* species and antigenic variation," *Trends Microbiol.*, 1:236-239, 1993.
 Barbour and Garon, "Linear plasmids of the bacterium *Borrelia burgdorferi* have covalently closed ends," *Science*, 237:409-411, 1987.
 Barbour, Burman, Carter, Kitten, Bergstrom, "Variable antigen genes of the relapsing fever agent *Borrelia hermsii* are activated by promoter addition," *Mol. Microbiol.*, 5:489-493, 1991a.
 Barbour, Carter, Burman, Freitag, Garon, Bergstrom, "Tandem insertion sequence-like elements define the expression site for variable antigen genes of *Borrelia hermsii*," *Infect. Immun.*, 59:390-397, 1991b.
 Barbour et al., "Structural analysis of the variable major proteins of *Borrelia hermsii*," *J. Exp. Med.*, 158:2127-2140, 1983.
 Barbour et al., "Variable major proteins of *Borrelia hermsii*," *J. Exp. Med.*, 156:1312-1324, 1982.
 Barstad et al., "Variable major proteins of *Borrelia hermsii*. Epitope mapping and partial sequence analysis of CNBr peptides," *J. Exp. Med.*, 161:1302-1314, 1985.
 Barthold, "Antigenic stability of *Borrelia burgdorferi* during chronic infections of immunocompetent mice," *Infect. Immun.*, 61:4955-4961, 1993.
 Barthold, Moody, Beck, "Susceptibility of laboratory rats to isolates of *Borrelia burgdorferi* from different geographic areas," *Am. J. Trop. Med. Hyg.*, 42:596-600, 1990.
 Borst and Geaves, "Programmed gene rearrangements altering gene expression," *Science*, 235:658-667, 1987.
 Borst, Bitter, McCulloch, Leeuwen, Rudenko, "Antigenic variation in malaria," *Cell*, 82:104, 1995.
 Burgdorfer, Barbour, Hayes, Benach, Grunwaldt, Davis, "Lyme disease, a tick-borne spirochetosis?," *Science*, 216: 1317-1319, 1982.

Carroll and Gheradini, "Membrane protein variations associated with in vitro passage of *Borrelia burgdorferi*," *Infect. Immun.*, 64:392-398, 1996.
 Carter et al., "A family of surface-exposed proteins of 20 kilodaltons in the genus *Borrelia*," *Infect. Immun.*, 62:2792-2799, 1994.
 Casjens, Delange III, Ley, Rosa, Huang, "Linear chromosomes of Lyme disease agent spirochetes: genetic diversity and conservation of gene order," *J. Bacteriol.*, 177: 2769-2780, 1995.
 Demolis, Mallet, Bussereau, Jacquet, "Improved strategy for large-scale DNA sequencing using DNase I cleavage for generating random subclones," *Biotechniques*, 18:453-457, 1995.
 Dever, Jorgensen, Barbour, "In vitro antimicrobial susceptibility testing of *Borrelia burgdorferi*: a microdilution MIC method and time-kill studies," *J. Clin. Microbiol.*, 30:2692-2697, 1992.
 Donelson, "Mechanisms of antigenic variation in *Borrelia hermsii* and African trypanosomes," *J. Biol. Chem.*, 270: 7783-7786, 1995.
 Fuchs, Jauris, Lottspeich, Preacmursic, Wilskie, Soutschek, "Molecular analysis and expression of a *Borrelia burgdorferi* gene encoding a 22 kDa protein (pC) in *E. coli*," *Mol. Microbiol.*, 6:503-509, 1992.
 Haas and Meyer, "The repertoire of silent pilus genes in *Neisseria gonorrhoeae*: evidence for gene conversion," *Cell*, 44:107-115, 1986.
 Hagblom, Segal, Billyard, So, "Intragenic recombination leads to pilus antigenic variation in *Neisseria gonorrhoeae*," *Nature*, 315:156-158, 1985.
 Hinnebusch, Bergstrom, Barbour, "Cloning and sequence analysis of linear plasmid telomeres of the bacterium *Borrelia burgdorferi*," *Mol. Microbiol.*, 4:811-820, 1990.
 Hofman and Baron, "Boxshade 3.21 [WWW Document] accessed on the World Wide Web at isrec.isbsib.ch:8080/software/BOX_form.html, 1996.
 Hudson, Frye, Quinn, Gherardini, "Increased expression of *Borrelia burgdorferi* vlsE in response to human endothelial cell membrane," *Mol. Microbiol.*, 41:229-239, 2001.
 Hughes and Johnson, "Methylated DNA in *Borrelia* species," *J. Bacteriol.*, 172:6602-6604, 1990.
 Indest, Howell, Jacobs, School-Meker, Norris, Phillip, "Analysis of *Borrelia burgdorferi* vlsE gene expression and recombination in the tick vector," *Infect. Immun.*, 69:7083-7090, 2001.
 Johnson et al., "Infection of Syrian hamsters with Lyme disease spirochetes," *J. Clin. Microbiol.*, 20:1099-1101, 1984.
 Jonsson, Ilver, Falk, Pepose, Normark, "Sequence changes in the pilus subunit lead to tropism variation of *Neisseria gonorrhoeae* to human tissue," *Mol. Microbiol.*, 13:403-416, 1994.
 Kitten and Barbour, "Juxtaposition of expressed variable antigen genes with a conserved telomere in the bacterium *Borrelia hermsii*," *Proc. Natl. Acad. Sci. USA*, 87:6077-6081, 1990.
 Kitten and Barbour, "The relapsing fever agent *Borrelia hermsii* has multiple copies of its chromosome and linear plasmids," *Genetics*, 132:311-324, 1992.
 Koomey, Gotschlich, Robbins, Bergstrom, Swanson, "Effects of recA mutations on pilus antigenic variation and phase transitions in *Neisseria gonorrhoeae*," *Genetics*, 117:391-398, 1987.
 Kriuchevnikov, Korenberg, Shcherbakov, Kovalevskii, Levin, "Identification of *borrelia* isolated in the USSR

- from *Ixodes persulcatus* Schulze ticks], *Zh Mikrobiol. Epidemiol. Immunobiol.*, 12:41-44, 1988.
- Kupsch, Knepper, Kuroki, Heuer, Meyer, "Variable opacity (Opa) outer membrane proteins account for the cell tropisms displayed by *Neisseria gonorrhoeae* for human leukocytes and epithelial cells," *EMBO. J.*, 12:641-650, 1993.
- Lambden, Robertson, Watt, "Biological properties of two distinct pilus types produced by isogenic variants of *Neisseria gonorrhoeae* P9," *J. Bacteriol.*, 141:393-396, 1980.
- Liang and Philipp, "Analysis of antibody response to invariable regions of VlsE, the variable surface antigen of *Borrelia burgdorferi*," *Infect. Immun.*, 67:6702-6706, 1999.
- Liang, Alvarez, Gu, Nowling, Ramamoorthy, Philipp, "An immunodominant conserved region within the variable domain of VlsE, the variable surface antigen of *Borrelia burgdorferi*," *J. Immunol.*, 163:5566-5573, 1999a.
- Liang, Aberer, Cinco, Gern, Hu, Lobet, Ruscio, Voet, Jr., Weynants, Philipp, "Antigenic conservation of an immunodominant invariable region of the VlsE lipoprotein among European pathogenic genospecies of *Borrelia burgdorferi* SL," *J. Infect. Dis.*, 182:1455-1462, 2000a.
- Livey, Gibbs, Schuster, Dorner, "Evidence for lateral transfer and recombination in OspC variation in Lyme disease *Borrelia*," *Mol. Microbiol.*, 18:257-269, 1995.
- Marconi, Konkell, Garon, "Variability of osp genes and gene products among species of Lyme disease spirochetes," *Infect. Immun.*, 61:2611-2617, 1993.
- Marconi, Samuels, Landry, Garon, "Analysis of the distribution and molecular heterogeneity of the ospD gene among the Lyme disease spirochetes: evidence for lateral gene exchange," *J. Bacteriol.*, 176:4572-4582, 1994.
- Margolis et al., "Homology between *Borrelia burgdorferi* OspC and members of the family of *Borrelia hermsii* variable major proteins," *Gene*, 143:105-110, 1994.
- Meier, Simon, Barbour, "Antigenic variation is associated with DNA rearrangements in a relapsing fever *Borrelia*," *Cell*, 41:403-409, 1985.
- Meyer, Mlawer, So, "Pilus expression in *Neisseria gonorrhoeae* involves chromosomal rearrangement," *Cell*, 30:45-52, 1982.
- Moody et al., "Lyme borreliosis in laboratory animals: effect of host species and in vitro passage of *Borrelia burgdorferi*," *Am. J. Trop. Med. Hyg.*, 43:87-92, 1990.
- Nassif, Lowry, Stenberg, O'Gaora, Ganji, So, "Antigenic variation of pilin regulates adhesion of *Neisseria meningitidis* to human epithelial cells," *Mol. Microbiol.*, 8:719-725, 1993.
- Norris, Carter, Howell, Barbour, "Low-passage-associated proteins of *Borrelia burgdorferi* B31: characterization and molecular cloning of OspD, a surface-exposed, plasmid-encoded lipoprotein," *Infect. Immun.*, 60:4662-4672, 1992.
- Norris et al., "High- and low-infectivity phenotypes of clonal populations of in vitro-cultured *Borrelia burgdorferi*," *Infect. Immun.*, 63:2206-2212, 1995.
- Norris et al., "Low-passage-associated proteins of *Borrelia burgdorferi* B31: characterization and molecular cloning of OspD, a surface exposed, plasmid-encoded lipoprotein," *Infect. Immun.*, 60:4662-4672, 1992.
- Persing, Mathiesen, Podzorski, Barthold, "Genetic stability of *Borrelia burgdorferi* recovered from chronically infected immunocompetent mice," *Infect. Immun.*, 62:3521-3527, 1994.

- Plasterk et al., "Transposition of structural genes to an expression sequence on a linear plasmid causes antigenic variation in the bacterium *Borrelia hermsii*," *Nature*, 318:257-263, 1985.
- Purser and Norris, "Correlation between plasmid content and infectivity in *Borrelia burgdorferi*," *Proc. Natl. Acad. Sci. USA*, 97:13865-13870, 2000.
- Restrepo and Barbour, "Antigen diversity in the bacterium *B. hermsii* through 'somatic' mutations in rearranged vmp genes," *Cell*, 78:867-876, 1994.
- Restrepo, Carter, Barbour, "Activation of a vmp pseudogene in *Borrelia hermsii*: an alternate mechanism of antigenic variation during relapsing fever," *Mol. Microbiol.*, 13:287-299, 1994.
- Restrepo, Kitten, Carter, Infante, Barbour, "Subtelomeric expression regions of *Borrelia hermsii* linear plasmids are highly polymorphic," *Mol. Microbiol.*, 6:3299-3311, 1992.
- Robertson and Meyer, "Genetic variation in pathogenic bacteria," *Trends Genet.*, 8:422-427, 1992.
- Rosa, Samuels, Hogan, Stevenson, Casjens, Tilly, "Directed insertion of a selectable marker into a circular plasmid of *Borrelia burgdorferi*," *J. Bacteriol.*, 178:5946-5953, 1996.
- Rosa, Schwan, Hogen, "Recombination between genes encoding major surface proteins A and B of *Borrelia burgdorferi*," *Mol. Microbiol.*, 6:3031-3040, 1992.
- Rudel, Van Putten, Gibbs, Haas, Meyer, "Interaction of two variable proteins (PilE and PilC) required for pilus-mediated adherence of *Neisseria gonorrhoeae* to human epithelial cells," *Mol. Microbiol.*, 6:3439-3450, 1992.
- Sadzienne, Rosa, Thompson, Hogan, Barbour, "Antibody-resistant mutations of *Borrelia burgdorferi*: in vitro selection and characterization," *J. Exp. Med.*, 176:799-809, 1992.
- Sambrook, Fritsch, Maniatis, "Molecular cloning: a laboratory manual," Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press, 1989.
- Sambrook, Fritsch, Maniatis, "Molecular cloning: a laboratory manual," Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press, 2001.
- Samuels, Mach, Garon, "Genetic transformation of the Lyme disease agent *Borrelia burgdorferi* with coumarin-resistant gyrB," *J. Bacteriol.*, 176:6045-6049, 1994.
- Schutzer, "Lyme disease: Molecular and immunologic approaches. In: *Current communications in cell and molecular biology*," J. Inglis and J. A. Witkowski, eds. (Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press).
- Schwann et al., "Changes in infectivity and plasmid profile of the Lyme disease spirochete, *Borrelia burgdorferi*, as a result of in vitro cultivation," *Infect. Immun.*, 56:1831-1836, 1988a.
- Schwann, Burgdorfer, Schrupp, Karstens, "The urinary bladder, a consistent source of *Borrelia burgdorferi* in experimentally infected white-footed mice (*Peromyscus leucopus*)," *J. Clin. Microbiol.*, 26:893-895, 1988b.
- Schwann, Karstens, Schrupp, Simpson, "Changes in antigenic reactivity of *Borrelia burgdorferi*, the Lyme disease spirochete, during persistent infection of mice," *Can. J. Microbiol.*, 37:450-454, 1991.
- Seal, Jackson, Daniels, "Isolation of a *Pseudomonas solanacearum*-specific DNA probe by subtraction hybridization and construction of species-specific oligonucleotide primers for sensitive detection by the polymerase chain reaction," *Appl. Environ. Microbiol.*, 58:3751-3758, 1992.

- Segal, Hagblom, Seifert, So, "Antigenic variation of gonococcal pilus involves assembly of separated silent gene segments," *Proc. Natl. Acad. Sci. USA*, 83:2177-2181, 1986.
- Seifert and So, "Genetic mechanisms of bacterial antigenic variation," *Microbiol. Rev.*, 52:327-336, 1988.
- Smith, Wiese, Wojzynski, Davison, Worley, "BCM Search Launcher—an integrated interface to molecular biology data base search and analysis services available on the World Wide Web," *Genome Res.*, 6:454-462, 1996.
- Steere, "Lyme disease," *N. Engl. J. Med.*, 321:586-596, 1989.
- Stevenson, Bockenstedt, Barthold, "Expression and gene sequence of outer surface protein C of *Borrelia burgdorferi* reisolated from chronically infected mice," *Infect. Immun.*, 62:3568-3571, 1994.
- Stoenner, Dodd, Larsen, "Antigenic variation of *Borrelia hermsii*," *J. Exp. Med.*, 156:1297-1311, 1982.
- Swanson and Koomey, "Mechanisms for variation of pili and outer membrane protein II in *Neisseria gonorrhoeae*," D. E. Berg and M. M. Howe, Eds. (Washington, D.C.: American Society for Microbiology).
- Thiessen et al., "Evolution of the *Borrelia burgdorferi* outer surface protein OspC," *J. Bacteriol.*, 177:3036-3044, 1995.
- TIGR, The Institute for Genomic Research (accessed on the World Wide Web at tigr.org), 2002.
- Wainwright, Pritchard, Seifert, "A conserved DNA sequence is required for efficient gonococcal pilin antigenic variation," *Mol. Microbiol.*, 13:75-87, 1994.

- Walker, Howell, You, Hoffmaster, Heath, Weinstock, Norris, "Physical map of the genome of *Treponema pallidum* subsp. *Pallidum* (Nichols)," *J. Bacteriol.*, 177:1797-1804, 1995.
- Wang, van Dam, Dankert, "Analysis of a VMP-like sequence (vls) locus in *Borrelia garinii* and Vls homologues among four *Borrelia burgdorferi* sensu lato species," *FEMS Microbiol. Lett.*, 3199:9-45, 2001.
- Wilske, Barbour, Bergstrom, Burman, Restrepo, Rosa, Schwan, Soutschek, Wallich, "Antigenic variation and strain heterogeneity in *Borrelia* spp," *Res. Microbiol.*, 143:583-596, 1992.
- Wu and Tokunaga, "Biogenesis of lipoproteins in bacteria," *Curr. Top. Microbiol. Immunol.*, 125:127-157, 1986.
- Xu, Kodner, Coleman, Johnson, "Correlation of plasmids with infectivity of *Borrelia burgdorferi* sensu stricto type strain B31," *Infect. Immun.*, 64:3870-3876, 1996.
- Xu and Johnson, "Analysis and comparison of plasmid profile of *Borrelia burgdorferi* sensu lato strains," *J. Clin. Microbiol.*, 33:2679-2685, 1995.
- Zhang, Hardman, Barbour, Norris, "Antigenic variation in Lyme disease borreliae by promiscuous recombination of VMP-like sequence cassettes," *Cell*, 89:275-285, 1997.
- Zhang and Norris, "Genetic variation of the *Borrelia burgdorferi* gene vlsE involves cassette-specific, segmental gene conversion," *Infect. Immun.*, 66:3698-3704, 1998a.
- Zhang and Norris, "Kinetics and in vivo induction of genetic variation of vlsE in *Borrelia burgdorferi*," *Infect. Immun.*, 66:3689-3697, 1998b.

SEQUENCE LISTING

<160> NUMBER OF SEQ ID NOS: 107

<210> SEQ ID NO 1

<211> LENGTH: 1227

<212> TYPE: DNA

<213> ORGANISM: *Borrelia burgdorferi*

<220> FEATURE:

<221> NAME/KEY: CDS

<222> LOCATION: (75)..(1142)

<400> SEQUENCE: 1

```

acctacactt gttaaaactc tctttttgag ttaagatgat aacttatact tttcattata      60
aggagacgat gaat  atg  aaa  aaa  att  tca  agt  gca  agt  tta  tta  aca  act      110
                    Met Lys Lys Ile Ser Ser Ala Ser Leu Leu Thr Thr
                    1          5          10
ttc  ttt  gtt  ttt  att  aat  tgt  aaa  agc  caa  gtt  gct  gat  aag  gac  gac      158
Phe Phe Val Phe Ile Asn Cys Lys Ser Gln Val Ala Asp Lys Asp Asp
                    15          20          25
cca  aca  aac  aaa  ttt  tac  caa  tct  gtc  ata  caa  tta  ggt  aac  gga  ttt      206
Pro Thr Asn Lys Phe Tyr Gln Ser Val Ile Gln Leu Gly Asn Gly Phe
                    30          35          40
ctt  gat  gta  ttc  aca  tct  ttt  ggt  ggg  tta  gta  gca  gag  gct  ttt  gga      254
Leu Asp Val Phe Thr Ser Phe Gly Gly Leu Val Ala Glu Ala Phe Gly
                    45          50          55          60
ttt  aaa  tca  gat  cca  aaa  aaa  tct  gat  gta  aaa  acc  tat  ttt  act  act      302
Phe Lys Ser Asp Pro Lys Lys Ser Asp Val Lys Thr Tyr Phe Thr Thr
                    65          70          75
gta  gct  gcc  aaa  ttg  gaa  aaa  aca  aaa  acc  gat  ctt  aat  agt  ttg  cct      350
Val Ala Ala Lys Leu Glu Lys Thr Lys Thr Asp Leu Asn Ser Leu Pro
                    80          85          90
aag  gaa  aaa  agc  gat  ata  agt  agt  acg  acg  ggg  aaa  cca  gat  agt  aca      398
Lys Glu Lys Ser Asp Ile Ser Ser Thr Thr Gly Lys Pro Asp Ser Thr

```

-continued

95	100	105	
ggt tct gtt gga act gcc gtt gag ggg gct att aag gaa gtt agc gag Gly Ser Val Gly Thr Ala Val Glu Gly Ala Ile Lys Glu Val Ser Glu 110 115 120			446
ttg ttg gat aag ctg gta aaa gct gta aag aca gct gag ggg gct tca Leu Leu Asp Lys Leu Val Lys Ala Val Lys Thr Ala Glu Gly Ala Ser 125 130 135 140			494
agt ggt act gct gca att gga gaa gtt gtg gct gat gct gat gct gca Ser Gly Thr Ala Ala Ile Gly Glu Val Val Ala Asp Ala Asp Ala Ala 145 150 155			542
aag gtt gct gat aag gcg agt gtg aag ggg att gct aag ggg ata aag Lys Val Ala Asp Lys Ala Ser Val Lys Gly Ile Ala Lys Gly Ile Lys 160 165 170			590
gag att gtt gaa gct gct ggg ggg agt gaa aag ctg aaa gct gtt gct Glu Ile Val Glu Ala Ala Gly Gly Ser Glu Lys Leu Lys Ala Val Ala 175 180 185			638
gct gct aaa ggg gag aat aat aaa ggg gca ggg aag ttg ttt ggg aag Ala Ala Lys Gly Glu Asn Asn Lys Gly Ala Gly Lys Leu Phe Gly Lys 190 195 200			686
gct ggt gct gct gct cat ggg gac agt gag gct gct agc aag gcg gct Ala Gly Ala Ala Ala His Gly Asp Ser Glu Ala Ala Ser Lys Ala Ala 205 210 215 220			734
ggt gct gtt agt gct gtt agt ggg gag cag ata tta agt gcg att gtt Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Ser Ala Ile Val 225 230 235			782
acg gct gct gat gcg gct gag cag gat gga aag aag cct gag gag gct Thr Ala Ala Asp Ala Ala Glu Gln Asp Gly Lys Lys Pro Glu Glu Ala 240 245 250			830
aaa aat ccg att gct gct gct att ggg gat aaa gat ggg ggt gcg gag Lys Asn Pro Ile Ala Ala Ala Ile Gly Asp Lys Asp Gly Gly Ala Glu 255 260 265			878
ttt ggt cag gat gag atg aag aag gat gat cag att gct gct gct att Phe Gly Gln Asp Glu Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Ile 270 275 280			926
gct ttg agg ggg atg gct aag gat gga aag ttt gct gtg aag gat ggt Ala Leu Arg Gly Met Ala Lys Asp Gly Lys Phe Ala Val Lys Asp Gly 285 290 295 300			974
gag aaa gag aag gct gag ggg gct att aag gga gct gct gag tct gca Glu Lys Glu Lys Ala Glu Gly Ala Ile Lys Gly Ala Ala Glu Ser Ala 305 310 315			1022
ggt cgc aaa gtt tta ggg gct att act ggg cta ata gga gac gcc gtg Val Arg Lys Val Leu Gly Ala Ile Thr Gly Leu Ile Gly Asp Ala Val 320 325 330			1070
agt tcc ggg cta agg aaa gtc ggt gat tca gtg aag gct gct agt aaa Ser Ser Gly Leu Arg Lys Val Gly Asp Ser Val Lys Ala Ala Ser Lys 335 340 345			1118
gaa aca cct cct gcc ttg aat aag tgatttaatt aagtgtatgg acacgactat Glu Thr Pro Pro Ala Leu Asn Lys 350 355			1172
gccctcatga ttgaggaaat agtcgagaga tatatataact aaaagataat aaata			1227

<210> SEQ ID NO 2
 <211> LENGTH: 356
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia burgdorferi

 <400> SEQUENCE: 2

Met Lys Lys Ile Ser Ser Ala Ser Leu Leu Thr Thr Phe Phe Val Phe
 1 5 10 15

-continued

```

Ile Asn Cys Lys Ser Gln Val Ala Asp Lys Asp Asp Pro Thr Asn Lys
      20                25                30
Phe Tyr Gln Ser Val Ile Gln Leu Gly Asn Gly Phe Leu Asp Val Phe
      35                40                45
Thr Ser Phe Gly Gly Leu Val Ala Glu Ala Phe Gly Phe Lys Ser Asp
      50                55                60
Pro Lys Lys Ser Asp Val Lys Thr Tyr Phe Thr Thr Val Ala Ala Lys
      65                70                75                80
Leu Glu Lys Thr Lys Thr Asp Leu Asn Ser Leu Pro Lys Glu Lys Ser
      85                90                95
Asp Ile Ser Ser Thr Thr Gly Lys Pro Asp Ser Thr Gly Ser Val Gly
      100               105               110
Thr Ala Val Glu Gly Ala Ile Lys Glu Val Ser Glu Leu Leu Asp Lys
      115               120               125
Leu Val Lys Ala Val Lys Thr Ala Glu Gly Ala Ser Ser Gly Thr Ala
      130               135               140
Ala Ile Gly Glu Val Val Ala Asp Ala Asp Ala Ala Lys Val Ala Asp
      145               150               155               160
Lys Ala Ser Val Lys Gly Ile Ala Lys Gly Ile Lys Glu Ile Val Glu
      165               170               175
Ala Ala Gly Gly Ser Glu Lys Leu Lys Ala Val Ala Ala Ala Lys Gly
      180               185               190
Glu Asn Asn Lys Gly Ala Gly Lys Leu Phe Gly Lys Ala Gly Ala Ala
      195               200               205
Ala His Gly Asp Ser Glu Ala Ala Ser Lys Ala Ala Gly Ala Val Ser
      210               215               220
Ala Val Ser Gly Glu Gln Ile Leu Ser Ala Ile Val Thr Ala Ala Asp
      225               230               235               240
Ala Ala Glu Gln Asp Gly Lys Lys Pro Glu Glu Ala Lys Asn Pro Ile
      245               250               255
Ala Ala Ala Ile Gly Asp Lys Asp Gly Gly Ala Glu Phe Gly Gln Asp
      260               265               270
Glu Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Ile Ala Leu Arg Gly
      275               280               285
Met Ala Lys Asp Gly Lys Phe Ala Val Lys Asp Gly Glu Lys Glu Lys
      290               295               300
Ala Glu Gly Ala Ile Lys Gly Ala Ala Glu Ser Ala Val Arg Lys Val
      305               310               315
Leu Gly Ala Ile Thr Gly Leu Ile Gly Asp Ala Val Ser Ser Gly Leu
      325               330               335
Arg Lys Val Gly Asp Ser Val Lys Ala Ala Ser Lys Glu Thr Pro Pro
      340               345               350
Ala Leu Asn Lys
      355

```

```

<210> SEQ ID NO 3
<211> LENGTH: 1141
<212> TYPE: DNA
<213> ORGANISM: Borrelia hermsii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(1062)

<400> SEQUENCE: 3

```

```

atg aga aaa aga ata agt gca ata ata atg act tta ttt atg gta tta
Met Arg Lys Arg Ile Ser Ala Ile Ile Met Thr Leu Phe Met Val Leu

```

-continued

1	5	10	15	
gta agc tgt aat agc ggt ggg gtt gcg gaa gat cct aaa act gtg tat				96
Val Ser Cys Asn Ser Gly Gly Val Ala Glu Asp Pro Lys Thr Val Tyr	20	25	30	
tta aca tct ata gct aat tta ggg aaa gga ttt tta gat gtt ttt gtg				144
Leu Thr Ser Ile Ala Asn Leu Gly Lys Gly Phe Leu Asp Val Phe Val	35	40	45	
act ttt gga gat atg gtt act gga gct ttt ggt att aag gca gat act				192
Thr Phe Gly Asp Met Val Thr Gly Ala Phe Gly Ile Lys Ala Asp Thr	50	55	60	
aag aaa agt gat ata ggg aag tat ttt act gat att gag agc act atg				240
Lys Lys Ser Asp Ile Gly Lys Tyr Phe Thr Asp Ile Glu Ser Thr Met	65	70	75	80
aca tca gtt aaa aag aag ttg caa gat gaa gtt gct aag aat ggt aac				288
Thr Ser Val Lys Lys Lys Leu Gln Asp Glu Val Ala Lys Asn Gly Asn	85	90	95	
tat cca aag gta aag aca gct gtt gac gaa ttt gtt gca atc tta gga				336
Tyr Pro Lys Val Lys Thr Ala Val Asp Glu Phe Val Ala Ile Leu Gly	100	105	110	
aag atc gag aaa gga gca aaa gaa gca tct aaa ggg gct act ggt gat				384
Lys Ile Glu Lys Gly Ala Lys Glu Ala Ser Lys Gly Ala Thr Gly Asp	115	120	125	
gtt att att ggg aat act gtt aag aat ggt gat gct gta cct gga gaa				432
Val Ile Ile Gly Asn Thr Val Lys Asn Gly Asp Ala Val Pro Gly Glu	130	135	140	
gca aca agt gtc aat tct ctt gtt aaa gga att aaa gaa ata gtt ggg				480
Ala Thr Ser Val Asn Ser Leu Val Lys Gly Ile Lys Glu Ile Val Gly	145	150	155	160
gta gtc ttg aag gaa ggt aag gca gat gct gat gct act aaa gat gat				528
Val Val Leu Lys Glu Gly Lys Ala Asp Ala Asp Ala Thr Lys Asp Asp	165	170	175	
agt aag aaa gat att ggt aaa tta ttt acc gca acc act gat gcg aat				576
Ser Lys Lys Asp Ile Gly Lys Leu Phe Thr Ala Thr Thr Asp Ala Asn	180	185	190	
aga gct gat aat gcg gca gct caa gca gct gca gcg tca ata gga gca				624
Arg Ala Asp Asn Ala Ala Ala Gln Ala Ala Ala Ala Ser Ile Gly Ala	195	200	205	
gtg aca ggt gct gat atc ttg caa gct ata gta caa tct aag gaa aat				672
Val Thr Gly Ala Asp Ile Leu Gln Ala Ile Val Gln Ser Lys Glu Asn	210	215	220	
cct gtt gca aat agt act gat gga att gaa aaa gca aca gat gca gct				720
Pro Val Ala Asn Ser Thr Asp Gly Ile Glu Lys Ala Thr Asp Ala Ala	225	230	235	240
gag att gca gtt gct cca gct aaa gat aat aaa aaa gag att aaa gat				768
Glu Ile Ala Val Ala Pro Ala Lys Asp Asn Lys Lys Glu Ile Lys Asp	245	250	255	
gga gca aaa aaa gac gca gtt att gct gca ggc att gca ctg cga gca				816
Gly Ala Lys Lys Asp Ala Val Ile Ala Ala Gly Ile Ala Leu Arg Ala	260	265	270	
atg gct aag aat ggt aca ttt tct att aaa aac aat gaa gat gcg gct				864
Met Ala Lys Asn Gly Thr Phe Ser Ile Lys Asn Asn Glu Asp Ala Ala	275	280	285	
gta acg acg ata aat agt gca gca gca agc gca gtg aac aag att tta				912
Val Thr Thr Ile Asn Ser Ala Ala Ala Ser Ala Val Asn Lys Ile Leu	290	295	300	
agc act cta ata ata gca ata agg aat aca gtt gat agt ggt tta aaa				960
Ser Thr Leu Ile Ile Ala Ile Arg Asn Thr Val Asp Ser Gly Leu Lys	305	310	315	320
aca ata aat gag gct ctt gct aca gtt aaa caa gaa gat aaa tct gta				1008

-continued

Thr Ile Asn Glu Ala Leu Ala Thr Val Lys Gln Glu Asp Lys Ser Val
 325 330 335

gaa gca act aat act gca gaa gca aca act agt ggt cag caa gcg aaa 1056
 Glu Ala Thr Asn Thr Ala Glu Ala Thr Thr Ser Gly Gln Gln Ala Lys
 340 345 350

aac tag ttaagggtaa atataaagga taaagttatt gtaagggaaa agcttttctt 1112
 Asn

gtttttaatg caggaatgta gtttctctg 1141

<210> SEQ ID NO 4
 <211> LENGTH: 353
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia hermsii

<400> SEQUENCE: 4

Met Arg Lys Arg Ile Ser Ala Ile Ile Met Thr Leu Phe Met Val Leu
 1 5 10 15

Val Ser Cys Asn Ser Gly Gly Val Ala Glu Asp Pro Lys Thr Val Tyr
 20 25 30

Leu Thr Ser Ile Ala Asn Leu Gly Lys Gly Phe Leu Asp Val Phe Val
 35 40 45

Thr Phe Gly Asp Met Val Thr Gly Ala Phe Gly Ile Lys Ala Asp Thr
 50 55 60

Lys Lys Ser Asp Ile Gly Lys Tyr Phe Thr Asp Ile Glu Ser Thr Met
 65 70 75 80

Thr Ser Val Lys Lys Lys Leu Gln Asp Glu Val Ala Lys Asn Gly Asn
 85 90 95

Tyr Pro Lys Val Lys Thr Ala Val Asp Glu Phe Val Ala Ile Leu Gly
 100 105 110

Lys Ile Glu Lys Gly Ala Lys Glu Ala Ser Lys Gly Ala Thr Gly Asp
 115 120 125

Val Ile Ile Gly Asn Thr Val Lys Asn Gly Asp Ala Val Pro Gly Glu
 130 135 140

Ala Thr Ser Val Asn Ser Leu Val Lys Gly Ile Lys Glu Ile Val Gly
 145 150 155 160

Val Val Leu Lys Glu Gly Lys Ala Asp Ala Asp Ala Thr Lys Asp Asp
 165 170 175

Ser Lys Lys Asp Ile Gly Lys Leu Phe Thr Ala Thr Thr Asp Ala Asn
 180 185 190

Arg Ala Asp Asn Ala Ala Ala Gln Ala Ala Ala Ala Ser Ile Gly Ala
 195 200 205

Val Thr Gly Ala Asp Ile Leu Gln Ala Ile Val Gln Ser Lys Glu Asn
 210 215 220

Pro Val Ala Asn Ser Thr Asp Gly Ile Glu Lys Ala Thr Asp Ala Ala
 225 230 235 240

Glu Ile Ala Val Ala Pro Ala Lys Asp Asn Lys Lys Glu Ile Lys Asp
 245 250 255

Gly Ala Lys Lys Asp Ala Val Ile Ala Ala Gly Ile Ala Leu Arg Ala
 260 265 270

Met Ala Lys Asn Gly Thr Phe Ser Ile Lys Asn Asn Glu Asp Ala Ala
 275 280 285

Val Thr Thr Ile Asn Ser Ala Ala Ala Ser Ala Val Asn Lys Ile Leu
 290 295 300

Ser Thr Leu Ile Ile Ala Ile Arg Asn Thr Val Asp Ser Gly Leu Lys
 305 310 315 320

-continued

Thr Ile Asn Glu Ala Leu Ala Thr Val Lys Gln Glu Asp Lys Ser Val
 325 330 335

Glu Ala Thr Asn Thr Ala Glu Ala Thr Thr Ser Gly Gln Gln Ala Lys
 340 345 350

Asn

<210> SEQ ID NO 5
 <211> LENGTH: 416
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(414)

<400> SEQUENCE: 5

aag ggg att gcg aag ggg ata aag ggg att gtt gcg gct gct ggg aag 48
 Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Ala Ala Ala Gly Lys
 1 5 10 15

gct ttt ggc aag gat ggt gat gcg ctg aca ggt gtt gca aaa gct gct 96
 Ala Phe Gly Lys Asp Gly Asp Ala Leu Thr Gly Val Ala Lys Ala Ala
 20 25 30

gag aat gat gct aac aag gat gcg ggg aag ttg ttt gct ggt aag aat 144
 Glu Asn Asp Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Lys Asn
 35 40 45

ggt aat gct ggt gct gct gac att gcg aag gcg gct gct gct gtt act 192
 Gly Asn Ala Gly Ala Ala Asp Ile Ala Lys Ala Ala Ala Ala Val Thr
 50 55 60

gcg gtt agt ggg gag cag ata cta aaa gct att gtt gag gcg gct ggt 240
 Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Glu Ala Ala Gly
 65 70 75 80

gat gcg gat cag gcg ggt gta aag gct gat gcg gct aag aat ccg att 288
 Asp Ala Asp Gln Ala Gly Val Lys Ala Asp Ala Ala Lys Asn Pro Ile
 85 90 95

gca gct gcg att ggg act gct gat gat ggt gct gcg ttt ggt aag gat 336
 Ala Ala Ala Ile Gly Thr Ala Asp Asp Gly Ala Ala Phe Gly Lys Asp
 100 105 110

gag atg aag aag aga aat gat aag att gtt gca gct att gtt ttg agg 384
 Glu Met Lys Lys Arg Asn Asp Lys Ile Val Ala Ala Ile Val Leu Arg
 115 120 125

ggg gtg cct aag gat gga aag ttt gct gct aa 416
 Gly Val Pro Lys Asp Gly Lys Phe Ala Ala
 130 135

<210> SEQ ID NO 6
 <211> LENGTH: 138
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 6

Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Ala Ala Ala Gly Lys
 1 5 10 15

Ala Phe Gly Lys Asp Gly Asp Ala Leu Thr Gly Val Ala Lys Ala Ala
 20 25 30

Glu Asn Asp Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Lys Asn
 35 40 45

Gly Asn Ala Gly Ala Ala Asp Ile Ala Lys Ala Ala Ala Ala Val Thr
 50 55 60

Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Glu Ala Ala Gly
 65 70 75 80

-continued

Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Gly
 65 70 75 80
 Ala Ala Ala Asn Gln Ala Gly Lys Lys Ala Ala Asp Ala Lys Asn Pro
 85 90 95
 Ile Ala Ala Ala Ile Gly Thr Ala Asp Asp Gly Ala Glu Phe Lys Asp
 100 105 110
 Asp Met Lys Lys Ser Asp Asn Ile Ala Ala Ile Val Leu Arg Gly
 115 120 125
 Val Pro Lys Asp Gly Lys Phe Ala Ala
 130 135

<210> SEQ ID NO 9
 <211> LENGTH: 428
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(426)

<400> SEQUENCE: 9

aag ggg att gcg aag ggg ata aag ggg att gtt gat gct gct ggg aag 48
 Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys
 1 5 10 15
 gct ttt ggt aag gag ggt gat gcg ctg aag gat gtt gca aaa gtt gct 96
 Ala Phe Gly Lys Glu Gly Asp Ala Leu Lys Asp Val Ala Lys Val Ala
 20 25 30
 gat gag aat ggg gat aac aag gat gcg ggg aag ttg ttt gct ggt gag 144
 Asp Glu Asn Gly Asp Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Glu
 35 40 45
 aat ggt aat gct ggt ggt gct gct gat gct gac att gcg aag gcg gct 192
 Asn Gly Asn Ala Gly Gly Ala Ala Asp Ala Asp Ile Ala Lys Ala Ala
 50 55 60
 gct gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt 240
 Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 65 70 75 80
 gag gcg gct ggt gct gcg gat cag gcg ggt gta aag gct gag gag gct 288
 Glu Ala Ala Gly Ala Ala Asp Gln Ala Gly Val Lys Ala Glu Glu Ala
 85 90 95
 aag aat ccg att gca gct gcg att ggg act gat gat gct ggt gcg gcg 336
 Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala Gly Ala Ala
 100 105 110
 gag ttt ggt gag aat gat atg aag aag aat gat aat att gct gcg gct 384
 Glu Phe Gly Glu Asn Asp Met Lys Lys Asn Asp Asn Ile Ala Ala Ala
 115 120 125
 att gtt ttg agg ggg gtg cct aag gat gga aag ttt gct gct aa 428
 Ile Val Leu Arg Gly Val Pro Lys Asp Gly Lys Phe Ala Ala
 130 135 140

<210> SEQ ID NO 10
 <211> LENGTH: 142
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 10

Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys
 1 5 10 15
 Ala Phe Gly Lys Glu Gly Asp Ala Leu Lys Asp Val Ala Lys Val Ala
 20 25 30
 Asp Glu Asn Gly Asp Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Glu
 35 40 45

-continued

Asn Gly Asn Ala Gly Gly Ala Ala Asp Ala Asp Ile Ala Lys Ala Ala
 50 55 60

Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 65 70 75 80

Glu Ala Ala Gly Ala Ala Asp Gln Ala Gly Val Lys Ala Glu Glu Ala
 85 90 95

Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala Gly Ala Ala
 100 105 110

Glu Phe Gly Glu Asn Asp Met Lys Lys Asn Asp Asn Ile Ala Ala Ala
 115 120 125

Ile Val Leu Arg Gly Val Pro Lys Asp Gly Lys Phe Ala Ala
 130 135 140

<210> SEQ ID NO 11
 <211> LENGTH: 426
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (3)..(425)

<400> SEQUENCE: 11

ag ggg att gcg aag ggg ata aag ggg att gtt gat gct gct ggg aag 47
 Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys
 1 5 10 15

gct ttt ggc aag gag ggt agt gcg ctg aag gat gtt aaa aca gtt gct 95
 Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr Val Ala
 20 25 30

gct gag aat gag gct aac aag gat gcg ggg aag ttg ttt gct ggt aag 143
 Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Lys
 35 40 45

aat ggt aat gct gat gct gct gat gct gct gac att gcg aag gcg gct 191
 Asn Gly Asn Ala Asp Ala Ala Asp Ala Ala Asp Ile Ala Lys Ala Ala
 50 55 60

ggt gct gtt agt gcg gtt agt ggg gag cag ata ctg aaa gct att gtt 239
 Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 65 70 75

gat ggt gct ggt gat gca gct aat cag gcg ggt aaa aag gct gct gag 287
 Asp Gly Ala Gly Asp Ala Ala Asn Gln Ala Gly Lys Lys Ala Ala Glu
 80 85 90 95

gct aag aat ccg att gcg gct gcg att ggg act aat gaa gct ggg gcg 335
 Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Glu Ala Gly Ala
 100 105 110

gag ttt ggt gat gat atg aag aag aga aat gat aag att gct gcg gct 383
 Glu Phe Gly Asp Asp Met Lys Lys Arg Asn Asp Lys Ile Ala Ala Ala
 115 120 125

att gtt ttg agg ggg gtg cct aag gat gga aag ttt gct gct a 426
 Ile Val Leu Arg Gly Val Pro Lys Asp Gly Lys Phe Ala Ala
 130 135 140

<210> SEQ ID NO 12
 <211> LENGTH: 141
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 12

Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala
 1 5 10 15

Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr Val Ala Ala
 20 25 30

-continued

Gly Lys Leu Asn Ala Ala Gly Ala Glu Gly Thr Thr Asn Ala Asp Ala
 20 25 30
 Gly Lys Leu Phe Val Lys Asn Ala Gly Asn Val Gly Gly Glu Ala Gly
 35 40 45
 Asp Ala Gly Lys Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln
 50 55 60
 Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly Gly Glu Lys Gln
 65 70 75 80
 Gly Lys Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly
 85 90 95
 Gly Ala Gly Asp Asn Asp Ala Ala Ala Phe Ala Thr Met Lys Lys
 100 105 110
 Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met Ala Lys Asp
 115 120 125
 Gly Gln Phe
 130

<210> SEQ ID NO 15
 <211> LENGTH: 390
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (2)..(388)

<400> SEQUENCE: 15

g ggg ata aag ggg att gtt gat gct gct gag aag gct gat gcg aag gaa 49
 Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu
 1 5 10 15
 ggg aag ttg gat gtg gct ggt gat gct ggt gaa act aac aag gat gct 97
 Gly Lys Leu Asp Val Ala Gly Asp Ala Gly Glu Thr Asn Lys Asp Ala
 20 25 30
 ggg aag ttg ttt gtg aag aag aat aat gag ggt ggt gaa gca aat gat 145
 Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp
 35 40 45
 gct ggg aag gct gct gct gcg gtt gct gct gtt agt ggg gag cag ata 193
 Ala Gly Lys Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile
 50 55 60
 tta aaa gcg att gtt gat gct gct gag ggt ggt gag aag cag ggt aag 241
 Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys
 65 70 75 80
 aag gct gcg gat gct aca aat ccg att gag gcg gct att ggg ggt gcg 289
 Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala
 85 90 95
 ggt gat aat gat gct gct gcg gcg ttt gct act atg aag aag gat gat 337
 Gly Asp Asn Asp Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp
 100 105 110
 cag att gct act gct atg gtt ctg agg gga atg gct aag gat ggg cag 385
 Gln Ile Ala Thr Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln
 115 120 125
 ttt gc 390
 Phe

<210> SEQ ID NO 16
 <211> LENGTH: 129
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 16

Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu

-continued

1	5	10	15
Gly Lys Leu Asp Val Ala Gly Asp Ala Gly Glu Thr Asn Lys Asp Ala	20	25	30
Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp	35	40	45
Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile	50	55	60
Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys	65	70	75
Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala	85	90	95
Gly Asp Asn Asp Ala Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp	100	105	110
Gln Ile Ala Thr Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln	115	120	125

Phe

<210> SEQ ID NO 17
 <211> LENGTH: 390
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (2)..(388)

<400> SEQUENCE: 17

g ggg ata aag ggg att gtt gat gct gct gag aag gct gat gcg aag gaa	49
Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu	
1 5 10 15	
ggg agg ttg gat gtg gct ggt gat gct ggt gaa act aac aag gat gct	97
Gly Arg Leu Asp Val Ala Gly Asp Ala Gly Glu Thr Asn Lys Asp Ala	
20 25 30	
ggg aag ttg ttt gtg aag aag aat aat gag ggt ggt gaa gca aat gat	145
Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp	
35 40 45	
gct ggg aag gct gct gct gcg gtt gct gct gtt agt ggg gag cag ata	193
Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile	
50 55 60	
tta aaa gcg att gtt gat gct gct gag ggt ggt gag aag cag ggt aag	241
Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys	
65 70 75 80	
aag gct gcg gat gct aca aat ccg att gag gcg gct att ggg ggt gcg	289
Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala	
85 90 95	
ggt gat aat gat gct gct gcg gcg ttt gct act atg aag aag gat gat	337
Gly Asp Asn Asp Ala Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp	
100 105 110	
cag att gct gct gct atg gtt ctg agg gga atg gct aag gat ggg cag	385
Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln	
115 120 125	
ttt gc	390
Phe	

<210> SEQ ID NO 18
 <211> LENGTH: 129
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii
 <400> SEQUENCE: 18

-continued

Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu
 1 5 10 15
 Gly Arg Leu Asp Val Ala Gly Asp Ala Gly Glu Thr Asn Lys Asp Ala
 20 25 30
 Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp
 35 40 45
 Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile
 50 55 60
 Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys
 65 70 75 80
 Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala
 85 90 95
 Gly Asp Asn Asp Ala Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp
 100 105 110
 Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln
 115 120 125

Phe

<210> SEQ ID NO 19
 <211> LENGTH: 339
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (2)..(337)

<400> SEQUENCE: 19

g ggg ata aag ggg att gtt gat gct gct ggt gaa act aac aag gat gct 49
 Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Glu Thr Asn Lys Asp Ala
 1 5 10 15
 ggg aag ttg ttt gtg aag aag aat aat gag ggt ggt gaa gca aat gat 97
 Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp
 20 25 30
 gct ggg aag gct gct gct gcg gtt gct gct gtt agt ggg gag cag ata 145
 Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile
 35 40 45
 tta aaa gcg att gtt gat gct gct gag ggt ggt gag aag cag ggt aag 193
 Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys
 50 55 60
 aag gct gcg gat gct aca aat ccg att gag gcg gct att ggg ggt aca 241
 Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Thr
 65 70 75 80
 aat gat aat gat gct gcg gcg ttt gct act atg aag aag gat gat cag 289
 Asn Asp Asn Asp Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp Gln
 85 90 95
 att gct gct gct atg gtt ctg agg gga atg gct aag gat ggg cag ttt 337
 Ile Ala Ala Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe
 100 105 110
 gc 339

<210> SEQ ID NO 20
 <211> LENGTH: 112
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 20

Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Glu Thr Asn Lys Asp Ala
 1 5 10 15
 Gly Lys Leu Phe Val Lys Lys Asn Asn Glu Gly Gly Glu Ala Asn Asp

-continued

20	25	30	
Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile			
35	40	45	
Leu Lys Ala Ile Val Asp Ala Ala Glu Gly Gly Glu Lys Gln Gly Lys			
50	55	60	
Lys Ala Ala Asp Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Thr			
65	70	75	80
Asn Asp Asn Asp Ala Ala Ala Phe Ala Thr Met Lys Lys Asp Asp Gln			
85	90	95	
Ile Ala Ala Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe			
100	105	110	

<210> SEQ ID NO 21
 <211> LENGTH: 21
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

 <400> SEQUENCE: 21

 ccagcaaaca acttccccgc c 21

<210> SEQ ID NO 22
 <211> LENGTH: 24
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

 <400> SEQUENCE: 22

 atccttaaac tccgccccat catc 24

<210> SEQ ID NO 23
 <211> LENGTH: 28
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

 <400> SEQUENCE: 23

 gagtgctgtg gagagtgtg ttgatgag 28

<210> SEQ ID NO 24
 <211> LENGTH: 27
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

 <400> SEQUENCE: 24

 ggggataaag gggattgtg atgctgc 27

<210> SEQ ID NO 25
 <211> LENGTH: 26
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

 <400> SEQUENCE: 25

-continued

gcaaactgcc catccttagc cattcc 26

<210> SEQ ID NO 26
 <211> LENGTH: 25
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

<400> SEQUENCE: 26

aaggggattg cgaaggggat aaagg 25

<210> SEQ ID NO 27
 <211> LENGTH: 27
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

<400> SEQUENCE: 27

ttagcagcaa actttccatc cttagcc 27

<210> SEQ ID NO 28
 <211> LENGTH: 5897
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 28

cggaaatcaa gccacctaaa acaacttccc aaaagtttct caaaaaatat tatattcagc 60
 agtaaattct ataagtcatt aattatttaa tactattcaa cagtaaattc tataagtcatt 120
 taattattta atactattca gcagtaaatt ctataagtca ttaattattt aatactattc 180
 agcagtaaat tctataagtc attaattatt taatactatt cagcagtaaa ttctataagt 240
 cattaattat ttaatactat tcagcagtaa attctataag tcattaatta tttaatacta 300
 ttcagcagta aattctataa gtcattaatt caattaggta acggattctt agatgtattc 360
 acctcttttg gtggattagt tgcagatgca ttggggttta aagctgatcc aaaaaaatct 420
 gatgtaaaaa cttattttga atctctagct aaaaaattag aagaaacaaa agatggttta 480
 actaagttgt ccaaaggtaa tgacgggtgat actggaaagg ctggtgatgc tgggtggggct 540
 ggtggtggcg ctagtgctgc aggtggcgct ggtgggattg agggcgctat aacagagatt 600
 agcaaattgt tagatgatat ggcaaaagct gctgcggaag ctgcaagtgc tgctactggt 660
 aatgcagcaa ttggggatgt tgtaattggt aatggtggag cagcaaaagg tggatgatgcg 720
 gagagtgtta atgggattgc taaggggata aaggggattg ttgatgctgc tgagaaggct 780
 gatgccaagg aaggaagtt ggatgtggct ggtgatgctg gtggggctgg tgggtggcgct 840
 ggtgctgcag gtggcgctgg tgggattgag ggcgctataa cagagattag caaatggtta 900
 gatgatatgg caaaagctgc tgcggttgct gcaagtgctg caagtgctgc tactggtaat 960
 gcagcaattg gggatgttgt taatggtaat gatggagcag caaaaggtgg tgatgcggcg 1020
 agtgtaaatg ggattgctaa ggggataaag gggattgttg atgctgctga gaaggctgat 1080
 gcgaaggaag ggaagttgga tgtggctggt gatgctggtg agggtaacaa ggatgctggg 1140
 aagctgtttg tgaagaagaa tgctgggtgat gaggggtggt aagcaaatga tgctgggaag 1200
 gctgctgctg cggttgctgc tgtagtggg gagcagatat taaaagcgat tgttgatgct 1260

-continued

gctgaggggtg atgataagca gggtaagaag gctgcgatg ctacaaatcc gattgagggcg	1320
gctattggggg gtgcgatgc ggggtgcta gctgagggcgt ttaataagat gaagaaggat	1380
gatcagattg ctgctgctat ggttctgagg ggaatggcta aggatgggca gtttgctttg	1440
aaggatgatg ctgctgctca tgaagggact gtaagaatg ctggtgatat ggcaaaggcc	1500
gctgcggaag ctgcaagtgc tgcaagtgct gctactggta gtacaacgat tggagatggt	1560
gtaagagtg gtgaggcaaa agatggatg gcgcgagtg ttaatggat tgctaagggg	1620
ataaagggga ttggtgatgc tgctgagaag gctgatgcca aggaagggaa gttggatgtg	1680
gctggtgctg ctggtacgac taacgtgaat gttgggaagt tgtttgtgaa gaataatggt	1740
aatgaggggtg gtgatgcaag tgatgctggg aaagctgctg ctgcggttgc tgctgtagt	1800
ggggagcaga tattaagc gattggtgat gctgctaaag atggtgataa gcaggggggt	1860
actgatgtaa aggatgctac aaatccgatt gaggcggcta ttgggggtac aaatgataat	1920
gatgctgagg cgtttgctac tatgaagaag gatgatcaga ttgctgctgc tatggttctg	1980
aggggaatgg ctaaggatgg gcagtttgc ttgaaggatg atgctgctaa ggatggatg	2040
aaaacggggg ttgctgcca tgctgaaaat ccgattgacg cggctattgg gggcgcgat	2100
gctgatgctg cggcgtttaa taaggagggg atgaagaagg atgatcagat tgctgctgct	2160
atggttctga ggggaatggc taaggatggg cagtttgc ttgacgaataa tgctgctgct	2220
catgaagggga ctgtaagaa tgctggtgat atggcaaaag ctgctgaggc tgctgcaagt	2280
gctgctactg gcaatgcagc aattggggat gttgtaaga gtaatggtgg agcagcagca	2340
aaagtggtg atgcgcgag tgttaatggg attgctaagg ggataaagg gattggtgat	2400
gctgctgaga aggctgatgc gaaggaaggg aagttggatg tggctggtgc tgctggtgaa	2460
actaacaagg atgctgggaa gttgtttgtg aagaagaatg gtgatgatgg tggatgatgca	2520
ggtgatgctg ggaaggctgc tgctgagggt gctgctgta gtggggagca gatattaaaa	2580
gcgattgttg atgctgctaa agatggatg aagacggggg ttactgatgt aaaggatgct	2640
acaaatccga ttgacgcggc tattgggggg agtgcggatg ctaatgctga ggcgtttgat	2700
aagatgaaga aggatgatca gattgctgct gctatggttc tgaggggaaat ggctaaggat	2760
gggcagtttg ctttgaagaa taatgatcat gataatcata aggggactgt taagaatgct	2820
gttgatatgg caaaggccgc tgaggaagct gcaagtgctg caagtgctgc tactggtaat	2880
gcagcgattg gggatggtt taagaatagt gggcagcag caaaagggtg tgaggcggcg	2940
agtgttaatg ggattgctaa ggggataaag gggatggtg atgctgctgg aaaggctgat	3000
gcgaaggaag ggaagtgga tgctactggt gctgagggtg cgactaacgt gaatgctggg	3060
aagttggttg tgaagagggc ggctgatgat ggtggtgatg cagatgatgc tgggaaggct	3120
gctgctgagg ttgctgcaag tgctgctact ggtaatgcag cgattggaga tgttgtaat	3180
ggtgatggtg caaaagcaaa aggtggtgat gcgcgagtg ttaatggat tgctaagggg	3240
ataaagggga ttggtgatgc tgctgagaag gctgatgcca aggaagggaa gttgaatgct	3300
gctggtgctg aggtacgac taacgcggat gctgggaagt tgtttgtgaa gaatgctggt	3360
aatgtgggtg gtgaagcagg tgatgctggg aaggctgctg ctgcggttgc tgctgtagt	3420
ggggagcaga tattaagc gattggtgat gctgctaaag atggtggtg gaagcagggt	3480
aagaaggctg cggatgctac aaatccgatt gacgcggcta ttgggggtac aaatgataat	3540
gatgctgctg cggcgtttgc tactatgaag aaggatgatc agattgctgc tgctatggtt	3600
ctgaggggaa tggctaagga tgggcaattt gctttgaagg atgctgctgc tgctcatgaa	3660

-continued

gggactgtta	agaatgctgt	tgatataata	aaggctgctg	cggaagctgc	aagtgctgca	3720
agtgctgcta	ctggtagtgc	agcaattggg	gatgttgta	atggtaatgg	agcaacagca	3780
aaagtggtg	atgcaagag	tgtaatggg	attgctaagg	ggataaagg	gattgttgat	3840
gctgctgaga	aggctgatgc	gaaggaagg	aagttggatg	tgctggtga	tgctggtgaa	3900
actaacaagg	atgctgggaa	gttgtttg	aagaacaatg	gtaatgagg	tggtgatgca	3960
gatgatgctg	ggaaggctgc	tgctgctg	gctgctgta	gtggggagca	gatattaaaa	4020
gcgattgttg	atgctgctaa	gggtggtgat	aagacgggta	agaataatgt	gaaggatgct	4080
gaaaatccga	ttgaggcggc	tattgggagt	agtgcggatg	ctgatgctgc	ggcgttta	4140
aaggagggga	tgaagaagga	tgatcagatt	gctgctgcta	tggttctgag	gggaatggct	4200
aaggatgggc	agtttgcttt	gacgaatgat	gctgctgctc	atgaaggac	tgtaagaat	4260
gctgttggga	gtgcaacaaa	taagaccgtt	gttgctttg	ctaacttgg	tcgaaagacc	4320
gtgcaagctg	ggttgaagaa	ggttggggat	gttgtaaga	atagtgagg	aaaagatgg	4380
gatgcggcga	gtgttaatgg	gattgctaag	gggataaagg	ggattgttga	tgctgctgag	4440
aaggctgatg	cgaaggaagg	gaagtggat	gtgctggtg	ctgctggtga	aactaacaag	4500
gatgctggga	agttgtttgt	gaagaagaat	aatgagggg	gtgaagcaa	tgatgctggg	4560
aaggctgctg	ctgctgctgc	tgctgttagt	ggggagcaga	tattaaaagc	gattgttgat	4620
gctgctaagg	atggatgatga	taagcagggt	aagaaggctg	aggatgctac	aatccgatt	4680
gacgcggcta	ttgggggtgc	aggtgctgct	gctaagctg	ctgctgctgc	taataatag	4740
aagaaggatg	atcagattgc	tgctgctatg	gttctgagg	gaatggctaa	ggatgggcag	4800
tttgctttga	cgaataatgc	tcataactaat	cataagggga	ctgttaagaa	tgctgttgat	4860
atgacaaaag	ctgctgctgc	tgctgcaagt	gctgcaagtg	ctgctactgg	taatgcagca	4920
attggggatg	ttgttaatgg	taatgatgga	gcagcaaaa	gtggtgatgc	ggcgagtgtt	4980
aatgggattg	ctaaggggat	aaaggggatt	gttgatgctg	ctgagaagg	tgatgcgaag	5040
gaagggaaat	tgaatgtggc	tggtgctgct	gggtgctgag	gtaacgagg	tgctgggaag	5100
ctgtttgtga	agaagaatgc	tggtgatcat	gggtggaag	caggtgatgc	tgggagggct	5160
gctgctgctg	ttgctgctgt	tagtggggag	cagatattaa	aagcgattgt	tgatgctgct	5220
aaggatggtg	gtgataagca	gggtaagaag	gctgaggatg	ctgaaaatcc	gattgacgcg	5280
gctattggga	gtacgggtgc	ggatgataat	gctgctgagg	cgtttgctac	tatgaagaag	5340
gatgatcaga	ttgctgctgc	tatggttctg	aggggaatgg	ctaaggatgg	gcagtttctg	5400
ttgaaggatg	ctgctcatga	taatcataag	gggactgtta	agaatgctgt	tgatataata	5460
aaggctactg	cggttgctgc	aagtgctgct	actggtagta	caacgattgg	ggatgttggt	5520
aagaatggtg	aggcaaaagg	tggtgaggcg	aagagtgtta	atgggattgc	taaggggata	5580
aaggggattg	ttgatgctgc	tggaaaggct	gatgcaagg	aaggaagt	gaatgtggct	5640
gggtgctgctg	gtgagggtaa	cgaggctgct	gggaagctgt	ttgtgtaaat	tactatagga	5700
ttagaactag	tgtacgatat	gagtcctttg	gttattttgc	agctgctaat	gaatttgaaa	5760
taagtgaagt	taaaattgcg	gatgttaatg	gaacacattt	tattgctaca	aaagagaaag	5820
aatattata	tgattcactt	gatttaagg	ctcgtggaaa	aatatttgaa	ataacttcaa	5880
agcgaatggt	taagctt					5897

-continued

```

<211> LENGTH: 300
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(300)

<400> SEQUENCE: 29

gtc att aat tat tta ata cta ttc agc agt aaa ttc tat aag tca tta      48
Val Ile Asn Tyr Leu Ile Leu Phe Ser Ser Lys Phe Tyr Lys Ser Leu
1           5           10           15

att caa tta ggt aac gga ttc tta gat gta ttc acc tct ttt ggt gga      96
Ile Gln Leu Gly Asn Gly Phe Leu Asp Val Phe Thr Ser Phe Gly Gly
          20           25           30

tta gtt gca gat gca ttg ggg ttt aaa gct gat cca aaa aaa tct gat      144
Leu Val Ala Asp Ala Leu Gly Phe Lys Ala Asp Pro Lys Lys Ser Asp
          35           40           45

gta aaa act tat ttt gaa tct cta gct aaa aaa tta gaa gaa aca aaa      192
Val Lys Thr Tyr Phe Glu Ser Leu Ala Lys Lys Leu Glu Glu Thr Lys
          50           55           60

gat ggt tta act aag ttg tcc aaa ggt aat gac ggt gat act gga aag      240
Asp Gly Leu Thr Lys Leu Ser Lys Gly Asn Asp Gly Asp Thr Gly Lys
65           70           75           80

gct ggt gat gct ggt ggg gct ggt ggt ggc gct agt gct gca ggt ggc      288
Ala Gly Asp Ala Gly Gly Ala Gly Gly Gly Ala Ser Ala Ala Gly Gly
          85           90           95

gct ggt ggg att
Ala Gly Gly Ile
          100

```

```

<210> SEQ ID NO 30
<211> LENGTH: 100
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 30

Val Ile Asn Tyr Leu Ile Leu Phe Ser Ser Lys Phe Tyr Lys Ser Leu
1           5           10           15

Ile Gln Leu Gly Asn Gly Phe Leu Asp Val Phe Thr Ser Phe Gly Gly
          20           25           30

Leu Val Ala Asp Ala Leu Gly Phe Lys Ala Asp Pro Lys Lys Ser Asp
          35           40           45

Val Lys Thr Tyr Phe Glu Ser Leu Ala Lys Lys Leu Glu Glu Thr Lys
          50           55           60

Asp Gly Leu Thr Lys Leu Ser Lys Gly Asn Asp Gly Asp Thr Gly Lys
65           70           75           80

Ala Gly Asp Ala Gly Gly Ala Gly Gly Gly Ala Ser Ala Ala Gly Gly
          85           90           95

Ala Gly Gly Ile
          100

```

```

<210> SEQ ID NO 31
<211> LENGTH: 102
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(102)

<400> SEQUENCE: 31

ggg ttt aaa gct gat cca aaa aaa tct gat gta aaa act tat ttt gaa      48
Gly Phe Lys Ala Asp Pro Lys Lys Ser Asp Val Lys Thr Tyr Phe Glu

```


-continued

1	5	10	15	
tct cta gct aaa aaa tta gaa gaa aca aaa gat ggt tta act aag ttg				96
Ser Leu Ala Lys Lys Leu Glu Glu Thr Lys Asp Gly Leu Thr Lys Leu				
	20	25	30	

tcc aaa	102
Ser Lys	

<210> SEQ ID NO 32
 <211> LENGTH: 34
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 32

Gly Phe Lys Ala Asp Pro Lys Lys Ser Asp Val Lys Thr Tyr Phe Glu	
1	5 10 15
Ser Leu Ala Lys Lys Leu Glu Glu Thr Lys Asp Gly Leu Thr Lys Leu	
	20 25 30

Ser Lys

<210> SEQ ID NO 33
 <211> LENGTH: 288
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(288)

<400> SEQUENCE: 33

gag ggc gct ata aca gag att agc aaa tgg tta gat gat atg gca aaa	48
Glu Gly Ala Ile Thr Glu Ile Ser Lys Trp Leu Asp Asp Met Ala Lys	
1	5 10 15

gct gct gcg gaa gct gca agt gct gct act ggt aat gca gca att ggg	96
Ala Ala Ala Glu Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly	
	20 25 30

gat gtt gtt aat ggt aat ggt gga gca gca aaa ggt ggt gat gcg gag	144
Asp Val Val Asn Gly Asn Gly Gly Ala Ala Lys Gly Gly Asp Ala Glu	
	35 40 45

agt gtt aat ggg att gct aag ggg ata aag ggg att gtt gat gct gct	192
Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala	
	50 55 60

gag aag gct gat gcg aag gaa ggg aag ttg gat gtg gct ggt gat gct	240
Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Asp Ala	
65	70 75 80

ggt ggg gct ggt ggt ggc gct ggt gct gca ggt ggc gct ggt ggg att	288
Gly Gly Ala Gly Gly Gly Ala Gly Ala Ala Gly Gly Ala Gly Gly Ile	
	85 90 95

<210> SEQ ID NO 34
 <211> LENGTH: 96
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 34

Glu Gly Ala Ile Thr Glu Ile Ser Lys Trp Leu Asp Asp Met Ala Lys	
1	5 10 15
Ala Ala Ala Glu Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly	
	20 25 30

Asp Val Val Asn Gly Asn Gly Gly Ala Ala Lys Gly Gly Asp Ala Glu	
	35 40 45

Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala	
	50 55 60

-continued

Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Asp Ala
65 70 75 80

Gly Gly Ala Gly Gly Gly Ala Gly Ala Ala Gly Gly Ala Gly Gly Ile
85 90 95

<210> SEQ ID NO 35
<211> LENGTH: 594
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(594)

<400> SEQUENCE: 35

gag ggc gct ata aca gag att agc aaa tgg tta gat gat atg gca aaa 48
Glu Gly Ala Ile Thr Glu Ile Ser Lys Trp Leu Asp Asp Met Ala Lys
1 5 10 15

gct gct gcg gtt gct gca agt gct gca agt gct gct act ggt aat gca 96
Ala Ala Ala Val Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Asn Ala
20 25 30

gca att ggg gat gtt gtt aat ggt aat gat gga gca gca aaa ggt ggt 144
Ala Ile Gly Asp Val Val Asn Gly Asn Asp Gly Ala Ala Lys Gly Gly
35 40 45

gat gcg gcg agt gtt aat ggg att gct aag ggg ata aag ggg att gtt 192
Asp Ala Ala Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val
50 55 60

gat gct gct gag aag gct gat gcg aag gaa ggg aag ttg gat gtg gct 240
Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala
65 70 75 80

ggt gat gct ggt gag ggt aac aag gat gct ggg aag ctg ttt gtg aag 288
Gly Asp Ala Gly Glu Gly Asn Lys Asp Ala Gly Lys Leu Phe Val Lys
85 90 95

aag aat gct ggt gat gag ggt ggt gaa gca aat gat gct ggg aag gct 336
Lys Asn Ala Gly Asp Glu Gly Gly Glu Ala Asn Asp Ala Gly Lys Ala
100 105 110

gct gct gcg gtt gct gct gtt agt ggg gag cag ata tta aaa gcg att 384
Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile
115 120 125

gtt gat gct gct gag ggt gat gat aag cag ggt aag aag gct gcg gat 432
Val Asp Ala Ala Glu Gly Asp Asp Lys Gln Gly Lys Lys Ala Ala Asp
130 135 140

gct aca aat ccg att gag gcg gct att ggg ggt gcg gat gcg ggt gct 480
Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala Asp Ala Gly Ala
145 150 155 160

aat gct gag gcg ttt aat aag atg aag aag gat gat cag att gct gct 528
Asn Ala Glu Ala Phe Asn Lys Met Lys Lys Asp Asp Gln Ile Ala Ala
165 170 175

gct atg gtt ctg agg gga atg gct aag gat ggg cag ttt gct ttg aag 576
Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Lys
180 185 190

gat gat gct gct gct cat 594
Asp Asp Ala Ala Ala His
195

<210> SEQ ID NO 36
<211> LENGTH: 198
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 36

Glu Gly Ala Ile Thr Glu Ile Ser Lys Trp Leu Asp Asp Met Ala Lys

-continued

1	5	10	15
Ala Ala Ala Val Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Asn Ala	20	25	30
Ala Ile Gly Asp Val Val Asn Gly Asn Asp Gly Ala Ala Lys Gly Gly	35	40	45
Asp Ala Ala Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val	50	55	60
Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala	65	70	75
Gly Asp Ala Gly Glu Gly Asn Lys Asp Ala Gly Lys Leu Phe Val Lys	85	90	95
Lys Asn Ala Gly Asp Glu Gly Gly Glu Ala Asn Asp Ala Gly Lys Ala	100	105	110
Ala Ala Ala Val Ala Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile	115	120	125
Val Asp Ala Ala Glu Gly Asp Asp Lys Gln Gly Lys Lys Ala Ala Asp	130	135	140
Ala Thr Asn Pro Ile Glu Ala Ala Ile Gly Gly Ala Asp Ala Gly Ala	145	150	155
Asn Ala Glu Ala Phe Asn Lys Met Lys Lys Asp Asp Gln Ile Ala Ala	165	170	175
Ala Met Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Lys	180	185	190
Asp Asp Ala Ala Ala His	195		

<210> SEQ ID NO 37
 <211> LENGTH: 573
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(573)

<400> SEQUENCE: 37

gaa ggg act gtt aag aat gct gtt gat atg gca aag gcc gct gcg gaa	48
Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Ala Glu	
1 5 10 15	
gct gca agt gct gca agt gct gct act ggt agt aca acg att gga gat	96
Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Ser Thr Thr Ile Gly Asp	
20 25 30	
gtt gtt aag agt ggt gag gca aaa gat ggt gat gcg gcg agt gtt aat	144
Val Val Lys Ser Gly Glu Ala Lys Asp Gly Asp Ala Ala Ser Val Asn	
35 40 45	
ggg att gct aag ggg ata aag ggg att gtt gat gct gct gag aag gct	192
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala	
50 55 60	
gat gcg aag gaa ggg aag ttg gat gtg gct ggt gct gct ggt acg act	240
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Thr Thr	
65 70 75 80	
aac gtg aat gtt ggg aag ttg ttt gtg aag aat aat ggt aat gag ggt	288
Asn Val Asn Val Gly Lys Leu Phe Val Lys Asn Asn Gly Asn Glu Gly	
85 90 95	
ggt gat gca agt gat gct ggg aaa gct gct gct gcg gtt gct gct gtt	336
Gly Asp Ala Ser Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val	
100 105 110	
agt ggg gag cag ata tta aaa gcg att gtt gat gct gct aaa gat ggt	384
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly	

-continued

115	120	125	
gat aag cag ggg gtt act gat gta aag gat gct aca aat ccg att gag Asp Lys Gln Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Glu 130 135 140			432
gcg gct att ggg ggt aca aat gat aat gat gct gcg gcg ttt gct act Ala Ala Ile Gly Gly Thr Asn Asp Asn Asp Ala Ala Ala Phe Ala Thr 145 150 155 160			480
atg aag aag gat gat cag att gct gct gct atg gtt ctg agg gga atg Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met 165 170 175			528
gct aag gat ggg cag ttt gct ttg aag gat gat gct gct aag gat Ala Lys Asp Gly Gln Phe Ala Leu Lys Asp Asp Ala Ala Lys Asp 180 185 190			573
<p><210> SEQ ID NO 38 <211> LENGTH: 191 <212> TYPE: PRT <213> ORGANISM: Borrelia garinii</p>			
<p><400> SEQUENCE: 38</p>			
Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Ala Glu 1 5 10 15			
Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Ser Thr Thr Ile Gly Asp 20 25 30			
Val Val Lys Ser Gly Glu Ala Lys Asp Gly Asp Ala Ala Ser Val Asn 35 40 45			
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala 50 55 60			
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Thr Thr 65 70 75 80			
Asn Val Asn Val Gly Lys Leu Phe Val Lys Asn Asn Gly Asn Glu Gly 85 90 95			
Gly Asp Ala Ser Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val 100 105 110			
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly 115 120 125			
Asp Lys Gln Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Glu 130 135 140			
Ala Ala Ile Gly Gly Thr Asn Asp Asn Asp Ala Ala Ala Phe Ala Thr 145 150 155 160			
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met 165 170 175			
Ala Lys Asp Gly Gln Phe Ala Leu Lys Asp Asp Ala Ala Lys Asp 180 185 190			
<p><210> SEQ ID NO 39 <211> LENGTH: 189 <212> TYPE: DNA <213> ORGANISM: Borrelia garinii <220> FEATURE: <221> NAME/KEY: CDS <222> LOCATION: (1)..(189)</p>			
<p><400> SEQUENCE: 39</p>			
ggt gat aaa acg ggg gtt gct gcg gat gct gaa aat ccg att gac gcg Gly Asp Lys Thr Gly Val Ala Ala Asp Ala Glu Asn Pro Ile Asp Ala 1 5 10 15			48
gct att ggg ggt gcg gat gct gat gct gcg gcg ttt aat aag gag ggg Ala Ile Gly Gly Ala Asp Ala Asp Ala Ala Ala Phe Asn Lys Glu Gly			96

-continued

	20		25		30		
atg aag aag gat gat cag att gct gct gct atg gtt ctg agg gga atg							144
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met							
	35		40		45		
gct aag gat ggg cag ttt gct ttg acg aat aat gct gct gct cat							189
Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asn Ala Ala Ala His							
	50		55		60		
 <210> SEQ ID NO 40							
<211> LENGTH: 63							
<212> TYPE: PRT							
<213> ORGANISM: Borrelia garinii							
 <400> SEQUENCE: 40							
Gly Asp Lys Thr Gly Val Ala Ala Asp Ala Glu Asn Pro Ile Asp Ala							
1	5		10		15		
Ala Ile Gly Gly Ala Asp Ala Asp Ala Ala Ala Phe Asn Lys Glu Gly							
	20		25		30		
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met							
	35		40		45		
Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asn Ala Ala Ala His							
	50		55		60		
 <210> SEQ ID NO 41							
<211> LENGTH: 576							
<212> TYPE: DNA							
<213> ORGANISM: Borrelia garinii							
<220> FEATURE:							
<221> NAME/KEY: CDS							
<222> LOCATION: (1)..(576)							
 <400> SEQUENCE: 41							
gaa ggg act gtt aag aat gct gtt gat atg gca aaa gct gct gcg gtt							48
Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Val							
1	5		10		15		
gct gca agt gct gct act ggc aat gca gca att ggg gat gtt gtt aag							96
Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Lys							
	20		25		30		
agt aat ggt gga gca gca gca aaa ggt ggt gat gcg gcg agt gtt aat							144
Ser Asn Gly Gly Ala Ala Ala Lys Gly Gly Asp Ala Ala Ser Val Asn							
	35		40		45		
ggg att gct aag ggg ata aag ggg att gtt gat gct gct gag aag gct							192
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala							
	50		55		60		
gat gcg aag gaa ggg aag ttg gat gtg gct ggt gct gct ggt gaa act							240
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Glu Thr							
	65		70		75		80
aac aag gat gct ggg aag ttg ttt gtg aag aag aat ggt gat gat ggt							288
Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn Gly Asp Asp Gly							
	85		90		95		
ggt gat gca ggt gat gct ggg aag gct gct gct gcg gtt gct gct gtt							336
Gly Asp Ala Gly Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val							
	100		105		110		
agt ggg gag cag ata tta aaa gcg att gtt gat gct gct aaa gat ggt							384
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly							
	115		120		125		
gat aag acg ggg gtt act gat gta aag gat gct aca aat ccg att gac							432
Asp Lys Thr Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Asp							
	130		135		140		
gcg gct att ggg ggg agt gcg gat gct aat gct gag gcg ttt gat aag							480
Ala Ala Ile Gly Gly Ser Ala Asp Ala Asn Ala Glu Ala Phe Asp Lys							

-continued

145	150	155	160	
atg aag aag gat gat cag att gct gct gct atg gtt ctg agg gga atg				528
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met				
	165	170	175	
gct aag gat ggg cag ttt gct ttg aag aat aat gat cat gat aat cat				576
Ala Lys Asp Gly Gln Phe Ala Leu Lys Asn Asn Asp His Asp Asn His				
	180	185	190	
 <210> SEQ ID NO 42				
<211> LENGTH: 192				
<212> TYPE: PRT				
<213> ORGANISM: Borrelia garinii				
 <400> SEQUENCE: 42				
Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Ala Val				
1	5	10	15	
Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Lys				
	20	25	30	
Ser Asn Gly Gly Ala Ala Ala Lys Gly Gly Asp Ala Ala Ser Val Asn				
	35	40	45	
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala				
	50	55	60	
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Glu Thr				
	65	70	75	80
Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn Gly Asp Asp Gly				
	85	90	95	
Gly Asp Ala Gly Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val				
	100	105	110	
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly				
	115	120	125	
Asp Lys Thr Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Asp				
	130	135	140	
Ala Ala Ile Gly Gly Ser Ala Asp Ala Asn Ala Glu Ala Phe Asp Lys				
	145	150	155	160
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met				
	165	170	175	
Ala Lys Asp Gly Gln Phe Ala Leu Lys Asn Asn Asp His Asp Asn His				
	180	185	190	
 <210> SEQ ID NO 43				
<211> LENGTH: 336				
<212> TYPE: DNA				
<213> ORGANISM: Borrelia garinii				
<220> FEATURE:				
<221> NAME/KEY: CDS				
<222> LOCATION: (1)..(336)				
 <400> SEQUENCE: 43				
aag ggg act gtt aag aat gct gtt gat atg gca aag gcc gct gag gaa				48
Lys Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Glu Glu				
1	5	10	15	
gct gca agt gct gca agt gct gct act ggt aat gca gcg att ggg gat				96
Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp				
	20	25	30	
gtt gtt aag aat agt ggg gca gca gca aaa ggt ggt gag gcg gcg agt				144
Val Val Lys Asn Ser Gly Ala Ala Ala Lys Gly Gly Glu Ala Ala Ser				
	35	40	45	
gtt aat ggg att gct aag ggg ata aag ggg att gtt gat gct gct gga				192
Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly				

-continued

50	55	60	
aag gct gat gcg aag gaa ggg aag ttg gat gct act ggt gct gag ggt			240
Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Ala Thr Gly Ala Glu Gly			
65	70	75	80
acg act aac gtg aat gct ggg aag ttg ttt gtg aag agg gcg gct gat			288
Thr Thr Asn Val Asn Ala Gly Lys Leu Phe Val Lys Arg Ala Ala Asp			
	85	90	95
gat ggt ggt gat gca gat gat gct ggg aag gct gct gct gcg gtt gct			336
Asp Gly Gly Asp Ala Asp Asp Ala Gly Lys Ala Ala Ala Ala Val Ala			
	100	105	110

<210> SEQ ID NO 44
 <211> LENGTH: 112
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 44

Lys Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Glu Glu			
1	5	10	15
Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp			
	20	25	30
Val Val Lys Asn Ser Gly Ala Ala Ala Lys Gly Gly Glu Ala Ala Ser			
	35	40	45
Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly			
	50	55	60
Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Ala Thr Gly Ala Glu Gly			
65	70	75	80
Thr Thr Asn Val Asn Ala Gly Lys Leu Phe Val Lys Arg Ala Ala Asp			
	85	90	95
Asp Gly Gly Asp Ala Asp Asp Ala Gly Lys Ala Ala Ala Ala Val Ala			
	100	105	110

<210> SEQ ID NO 45
 <211> LENGTH: 522
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(522)

<400> SEQUENCE: 45

gca agt gct gct act ggt aat gca gcg att gga gat gtt gtt aat ggt			48
Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Asn Gly			
1	5	10	15
gat gtg gca aaa gca aaa ggt ggt gat gcg gcg agt gtt aat ggg att			96
Asp Val Ala Lys Ala Lys Gly Gly Asp Ala Ala Ser Val Asn Gly Ile			
	20	25	30
gct aag ggg ata aag ggg att gtt gat gct gct gag aag gct gat gcg			144
Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala			
	35	40	45
aag gaa ggg aag ttg aat gct gct ggt gct gag ggt acg act aac gcg			192
Lys Glu Gly Lys Leu Asn Ala Ala Gly Ala Glu Gly Thr Thr Asn Ala			
	50	55	60
gat gct ggg aag ttg ttt gtg aag aat gct ggt aat gtg ggt ggt gaa			240
Asp Ala Gly Lys Leu Phe Val Lys Asn Ala Gly Asn Val Gly Gly Glu			
65	70	75	80
gca ggt gat gct ggg aag gct gct gct gcg gtt gct gct gtt agt ggg			288
Ala Gly Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val Ser Gly			
	85	90	95
gag cag ata tta aaa gcg att gtt gat gct gct aag gat ggt ggt gag			336

-continued

Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Asp	Ala	Ala	Lys	Asp	Gly	Gly	Glu	
			100					105					110			
aag	cag	ggt	aag	aag	gct	gcg	gat	gct	aca	aat	ccg	att	gac	gcg	gct	384
Lys	Gln	Gly	Lys	Lys	Ala	Ala	Asp	Ala	Thr	Asn	Pro	Ile	Asp	Ala	Ala	
		115					120					125				
att	ggg	ggt	aca	aat	gat	aat	gat	gct	gct	gcg	gcg	ttt	gct	act	atg	432
Ile	Gly	Gly	Thr	Asn	Asp	Asn	Asp	Ala	Ala	Ala	Ala	Phe	Ala	Thr	Met	
	130					135					140					
aag	aag	gat	gat	cag	att	gct	gct	gct	atg	ggt	ctg	agg	gga	atg	gct	480
Lys	Lys	Asp	Asp	Gln	Ile	Ala	Ala	Ala	Met	Val	Leu	Arg	Gly	Met	Ala	
		145			150					155					160	
aag	gat	ggg	caa	ttt	gct	ttg	aag	gat	gct	gct	gct	gct	cat			522
Lys	Asp	Gly	Gln	Phe	Ala	Leu	Lys	Asp	Ala	Ala	Ala	Ala	His			
			165								170					

<210> SEQ ID NO 46
 <211> LENGTH: 174
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 46

Ala	Ser	Ala	Ala	Thr	Gly	Asn	Ala	Ala	Ile	Gly	Asp	Val	Val	Asn	Gly
1				5					10					15	
Asp	Val	Ala	Lys	Ala	Lys	Gly	Gly	Asp	Ala	Ala	Ser	Val	Asn	Gly	Ile
		20						25					30		
Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	Asp	Ala	Ala	Glu	Lys	Ala	Asp	Ala
		35					40					45			
Lys	Glu	Gly	Lys	Leu	Asn	Ala	Ala	Gly	Ala	Glu	Gly	Thr	Thr	Asn	Ala
	50					55					60				
Asp	Ala	Gly	Lys	Leu	Phe	Val	Lys	Asn	Ala	Gly	Asn	Val	Gly	Gly	Glu
	65				70					75					80
Ala	Gly	Asp	Ala	Gly	Lys	Ala	Ala	Ala	Ala	Val	Ala	Ala	Val	Ser	Gly
			85						90					95	
Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Asp	Ala	Ala	Lys	Asp	Gly	Gly	Glu
			100					105					110		
Lys	Gln	Gly	Lys	Lys	Ala	Ala	Asp	Ala	Thr	Asn	Pro	Ile	Asp	Ala	Ala
		115					120						125		
Ile	Gly	Gly	Thr	Asn	Asp	Asn	Asp	Ala	Ala	Ala	Ala	Phe	Ala	Thr	Met
	130					135					140				
Lys	Lys	Asp	Asp	Gln	Ile	Ala	Ala	Ala	Met	Val	Leu	Arg	Gly	Met	Ala
	145				150					155					160
Lys	Asp	Gly	Gln	Phe	Ala	Leu	Lys	Asp	Ala	Ala	Ala	Ala	Ala	His	
			165											170	

<210> SEQ ID NO 47
 <211> LENGTH: 585
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(585)

<400> SEQUENCE: 47

gaa	ggg	act	ggt	aag	aat	gct	ggt	gat	ata	ata	aag	gct	gct	gcg	gaa	48
Glu	Gly	Thr	Val	Lys	Asn	Ala	Val	Asp	Ile	Ile	Lys	Ala	Ala	Ala	Glu	
1				5					10					15		
gct	gca	agt	gct	gca	agt	gct	gct	act	ggg	agt	gca	gca	att	ggg	gat	96
Ala	Ala	Ser	Ala	Ala	Ser	Ala	Ala	Thr	Gly	Ser	Ala	Ala	Ile	Gly	Asp	
			20						25					30		

-continued

ggt ggt aat ggt aat gga gca aca gca aaa ggt ggt gat gcg aag agt	144
Val Val Asn Gly Asn Gly Ala Thr Ala Lys Gly Gly Asp Ala Lys Ser	
35 40 45	
ggt aat ggg att gct aag ggg ata aag ggg att gtt gat gct gct gag	192
Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu	
50 55 60	
aag gct gat gcg aag gaa ggg aag ttg gat gtg gct ggt gat gct ggt	240
Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Asp Ala Gly	
65 70 75 80	
gaa act aac aag gat gct ggg aag ttg ttt gtg aag aac aat ggt aat	288
Glu Thr Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Asn Asn Gly Asn	
85 90 95	
gag ggt ggt gat gca gat gat gct ggg aag gct gct gct gcg gtt gct	336
Glu Gly Gly Asp Ala Asp Asp Ala Gly Lys Ala Ala Ala Val Ala	
100 105 110	
gct gtt agt ggg gag cag ata tta aaa gcg att gtt gat gct gct aag	384
Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys	
115 120 125	
ggt ggt gat aag acg ggt aag aat aat gtg aag gat gct gaa aat ccg	432
Gly Gly Asp Lys Thr Gly Lys Asn Asn Val Lys Asp Ala Glu Asn Pro	
130 135 140	
att gag gcg gct att ggg agt agt gcg gat gct gat gct gcg gcg ttt	480
Ile Glu Ala Ala Ile Gly Ser Ser Ala Asp Ala Asp Ala Ala Phe	
145 150 155 160	
aat aag gag ggg atg aag aag gat gat cag att gct gct gct atg gtt	528
Asn Lys Glu Gly Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val	
165 170 175	
ctg agg gga atg gct aag gat ggg cag ttt gct ttg acg aat gat gct	576
Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asp Ala	
180 185 190	
gct gct cat	585
Ala Ala His	
195	

<210> SEQ ID NO 48

<211> LENGTH: 195

<212> TYPE: PRT

<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 48

Glu Gly Thr Val Lys Asn Ala Val Asp Ile Ile Lys Ala Ala Ala Glu	
1 5 10 15	
Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Ser Ala Ala Ile Gly Asp	
20 25 30	
Val Val Asn Gly Asn Gly Ala Thr Ala Lys Gly Gly Asp Ala Lys Ser	
35 40 45	
Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu	
50 55 60	
Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Asp Ala Gly	
65 70 75 80	
Glu Thr Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Asn Asn Gly Asn	
85 90 95	
Glu Gly Gly Asp Ala Asp Asp Ala Gly Lys Ala Ala Ala Ala Val Ala	
100 105 110	
Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys	
115 120 125	
Gly Gly Asp Lys Thr Gly Lys Asn Asn Val Lys Asp Ala Glu Asn Pro	
130 135 140	

-continued

Ile Glu Ala Ala Ile Gly Ser Ser Ala Asp Ala Asp Ala Ala Ala Phe
 145 150 155 160
 Asn Lys Glu Gly Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val
 165 170 175
 Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asp Ala
 180 185 190
 Ala Ala His
 195

<210> SEQ ID NO 49
 <211> LENGTH: 591
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(591)

<400> SEQUENCE: 49

gaa ggg act gtt aag aat gct gtt ggg agt gca aca aat aag acc gtt 48
 Glu Gly Thr Val Lys Asn Ala Val Gly Ser Ala Thr Asn Lys Thr Val
 1 5 10 15
 gtt gct ttg gct aac ttg gtt cga aag acc gtg caa gct ggg ttg aag 96
 Val Ala Leu Ala Asn Leu Val Arg Lys Thr Val Gln Ala Gly Leu Lys
 20 25 30
 aag gtt ggg gat gtt gtt aag aat agt gag gca aaa gat ggt gat gcg 144
 Lys Val Gly Asp Val Val Lys Asn Ser Glu Ala Lys Asp Gly Asp Ala
 35 40 45
 gcg agt gtt aat ggg att gct aag ggg ata aag ggg att gtt gat gct 192
 Ala Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala
 50 55 60
 gct gag aag gct gat gcg aag gaa ggg aag ttg gat gtg gct ggt gct 240
 Ala Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala
 65 70 75 80
 gct ggt gaa act aac aag gat gct ggg aag ttg ttt gtg aag aag aat 288
 Ala Gly Glu Thr Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn
 85 90 95
 aat gag ggt ggt gaa gca aat gat gct ggg aag gct gct gct gcg gtt 336
 Asn Glu Gly Gly Glu Ala Asn Asp Ala Gly Lys Ala Ala Ala Ala Val
 100 105 110
 gct gct gtt agt ggg gag cag ata tta aaa gcg att gtt gat gct gct 384
 Ala Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala
 115 120 125
 aag gat ggt gat gat aag cag ggt aag aag gct gag gat gct aca aat 432
 Lys Asp Gly Asp Asp Lys Gln Gly Lys Lys Ala Glu Asp Ala Thr Asn
 130 135 140
 ccg att gac gcg gct att ggg ggt gca ggt gcg ggt gct aat gct gct 480
 Pro Ile Asp Ala Ala Ile Gly Gly Ala Gly Ala Gly Ala Asn Ala Ala
 145 150 155 160
 gcg gcg ttt aat aat atg aag aag gat gat cag att gct gct gct atg 528
 Ala Ala Phe Asn Asn Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met
 165 170 175
 gtt ctg agg gga atg gct aag gat ggg cag ttt gct ttg acg aat aat 576
 Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asn
 180 185 190
 gct cat act aat cat 591
 Ala His Thr Asn His
 195

<210> SEQ ID NO 50
 <211> LENGTH: 197
 <212> TYPE: PRT

-continued

<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 50

Glu Gly Thr Val Lys Asn Ala Val Gly Ser Ala Thr Asn Lys Thr Val
 1 5 10 15
 Val Ala Leu Ala Asn Leu Val Arg Lys Thr Val Gln Ala Gly Leu Lys
 20 25 30
 Lys Val Gly Asp Val Val Lys Asn Ser Glu Ala Lys Asp Gly Asp Ala
 35 40 45
 Ala Ser Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala
 50 55 60
 Ala Glu Lys Ala Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala
 65 70 75 80
 Ala Gly Glu Thr Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn
 85 90 95
 Asn Glu Gly Gly Glu Ala Asn Asp Ala Gly Lys Ala Ala Ala Val
 100 105 110
 Ala Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala
 115 120 125
 Lys Asp Gly Asp Asp Lys Gln Gly Lys Lys Ala Glu Asp Ala Thr Asn
 130 135 140
 Pro Ile Asp Ala Ala Ile Gly Gly Ala Gly Ala Gly Ala Asn Ala Ala
 145 150 155 160
 Ala Ala Phe Asn Asn Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met
 165 170 175
 Val Leu Arg Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Thr Asn Asn
 180 185 190
 Ala His Thr Asn His
 195

<210> SEQ ID NO 51

<211> LENGTH: 594

<212> TYPE: DNA

<213> ORGANISM: Borrelia garinii

<220> FEATURE:

<221> NAME/KEY: CDS

<222> LOCATION: (1)..(594)

<400> SEQUENCE: 51

aag ggg act gtt aag aat gct gtt gat atg aca aaa gct gct gcg gtt 48
 Lys Gly Thr Val Lys Asn Ala Val Asp Met Thr Lys Ala Ala Ala Val
 1 5 10 15
 gct gca agt gct gca agt gct gct act ggt aat gca gca att ggg gat 96
 Ala Ala Ser Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp
 20 25 30
 gtt gtt aat ggt aat gat gga gca gca aaa ggt ggt gat gcg gcg agt 144
 Val Val Asn Gly Asn Asp Gly Ala Ala Lys Gly Gly Asp Ala Ala Ser
 35 40 45
 gtt aat ggg att gct aag ggg ata aag ggg att gtt gat gct gct gag 192
 Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu
 50 55 60
 aag gct gat gcg aag gaa ggg aag ttg aat gtg gct ggt gct gct ggt 240
 Lys Ala Asp Ala Lys Glu Gly Lys Leu Asn Val Ala Gly Ala Ala Gly
 65 70 75 80
 gct gag ggt aac gag gct gct ggg aag ctg ttt gtg aag aag aat gct 288
 Ala Glu Gly Asn Glu Ala Ala Gly Lys Leu Phe Val Lys Lys Asn Ala
 85 90 95
 ggt gat cat ggt ggt gaa gca ggt gat gct ggg agg gct gct gct gcg 336

-continued

Gly	Asp	His	Gly	Gly	Glu	Ala	Gly	Asp	Ala	Gly	Arg	Ala	Ala	Ala	Ala			
			100					105					110					
ggt	gct	gct	ggt	agt	ggg	gag	cag	ata	tta	aaa	gcg	att	ggt	gat	gct		384	
Val	Ala	Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Asp	Ala			
		115					120					125						
gct	aag	gat	ggt	ggt	gat	aag	cag	ggt	aag	aag	gct	gag	gat	gct	gaa		432	
Ala	Lys	Asp	Gly	Gly	Asp	Lys	Gln	Gly	Lys	Lys	Ala	Glu	Asp	Ala	Glu			
		130				135					140							
aat	ccg	att	gac	gcg	gct	att	ggg	agt	acg	ggt	gcg	gat	gat	aat	gct		480	
Asn	Pro	Ile	Asp	Ala	Ala	Ile	Gly	Ser	Thr	Gly	Ala	Asp	Asp	Asn	Ala			
145					150					155					160			
gct	gag	gcg	ttt	gct	act	atg	aag	aag	gat	gat	cag	att	gct	gct	gct		528	
Ala	Glu	Ala	Phe	Ala	Thr	Met	Lys	Lys	Asp	Asp	Gln	Ile	Ala	Ala	Ala			
			165						170					175				
atg	ggt	ctg	agg	gga	atg	gct	aag	gat	ggg	cag	ttt	gct	ttg	aag	gat		576	
Met	Val	Leu	Arg	Gly	Met	Ala	Lys	Asp	Gly	Gln	Phe	Ala	Leu	Lys	Asp			
			180					185					190					
gct	gct	cat	gat	aat	cat												594	
Ala	Ala	His	Asp	Asn	His													
		195																

<210> SEQ ID NO 52
<211> LENGTH: 198
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 52

Lys	Gly	Thr	Val	Lys	Asn	Ala	Val	Asp	Met	Thr	Lys	Ala	Ala	Ala	Val			
1				5					10						15			
Ala	Ala	Ser	Ala	Ala	Ser	Ala	Ala	Thr	Gly	Asn	Ala	Ala	Ile	Gly	Asp			
		20						25					30					
Val	Val	Asn	Gly	Asn	Asp	Gly	Ala	Ala	Lys	Gly	Gly	Asp	Ala	Ala	Ser			
		35				40						45						
Val	Asn	Gly	Ile	Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	Asp	Ala	Ala	Glu			
	50					55					60							
Lys	Ala	Asp	Ala	Lys	Glu	Gly	Lys	Leu	Asn	Val	Ala	Gly	Ala	Ala	Gly			
65					70					75					80			
Ala	Glu	Gly	Asn	Glu	Ala	Ala	Gly	Lys	Leu	Phe	Val	Lys	Lys	Asn	Ala			
			85						90					95				
Gly	Asp	His	Gly	Gly	Glu	Ala	Gly	Asp	Ala	Gly	Arg	Ala	Ala	Ala	Ala			
		100						105					110					
Val	Ala	Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Asp	Ala			
		115					120						125					
Ala	Lys	Asp	Gly	Gly	Asp	Lys	Gln	Gly	Lys	Lys	Ala	Glu	Asp	Ala	Glu			
	130					135					140							
Asn	Pro	Ile	Asp	Ala	Ala	Ile	Gly	Ser	Thr	Gly	Ala	Asp	Asp	Asn	Ala			
145					150					155					160			
Ala	Glu	Ala	Phe	Ala	Thr	Met	Lys	Lys	Asp	Asp	Gln	Ile	Ala	Ala	Ala			
			165						170					175				
Met	Val	Leu	Arg	Gly	Met	Ala	Lys	Asp	Gly	Gln	Phe	Ala	Leu	Lys	Asp			
			180					185					190					
Ala	Ala	His	Asp	Asn	His													
		195																

<210> SEQ ID NO 53
<211> LENGTH: 261
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii

-continued

```

<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(261)

<400> SEQUENCE: 53

aag ggg act gtt aag aat gct gtt gat ata ata aag gct act gcg gtt      48
Lys Gly Thr Val Lys Asn Ala Val Asp Ile Ile Lys Ala Thr Ala Val
1          5          10          15

gct gca agt gct gct act ggt agt aca acg att ggg gat gtt gtt aag      96
Ala Ala Ser Ala Ala Thr Gly Ser Thr Thr Ile Gly Asp Val Val Lys
          20          25          30

aat ggt gag gca aaa ggt ggt gag gcg aag agt gtt aat ggg att gct      144
Asn Gly Glu Ala Lys Gly Gly Glu Ala Lys Ser Val Asn Gly Ile Ala
          35          40          45

aag ggg ata aag ggg att gtt gat gct gct gga aag gct gat gcg aag      192
Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala Asp Ala Lys
          50          55          60

gaa ggg aag ttg aat gtg gct ggt gct gct ggt gag ggt aac gag gct      240
Glu Gly Lys Leu Asn Val Ala Gly Ala Ala Gly Glu Gly Asn Glu Ala
65          70          75          80

gct ggg aag ctg ttt gtg taa      261
Ala Gly Lys Leu Phe Val
          85

```

```

<210> SEQ ID NO 54
<211> LENGTH: 86
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

```

```

<400> SEQUENCE: 54

Lys Gly Thr Val Lys Asn Ala Val Asp Ile Ile Lys Ala Thr Ala Val
1          5          10          15

Ala Ala Ser Ala Ala Thr Gly Ser Thr Thr Ile Gly Asp Val Val Lys
          20          25          30

Asn Gly Glu Ala Lys Gly Gly Glu Ala Lys Ser Val Asn Gly Ile Ala
          35          40          45

Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala Asp Ala Lys
          50          55          60

Glu Gly Lys Leu Asn Val Ala Gly Ala Ala Gly Glu Gly Asn Glu Ala
65          70          75          80

Ala Gly Lys Leu Phe Val
          85

```

```

<210> SEQ ID NO 55
<211> LENGTH: 213
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(213)

```

```

<400> SEQUENCE: 55

gta aat tac tat agg att aga act agt gta cga tat gag tcc ttt ggt      48
Val Asn Tyr Tyr Arg Ile Arg Thr Ser Val Arg Tyr Glu Ser Phe Gly
1          5          10          15

tat ttt gca gct gct aat gaa ttt gaa ata agt gaa gtt aaa att gcg      96
Tyr Phe Ala Ala Ala Asn Glu Phe Glu Ile Ser Glu Val Lys Ile Ala
          20          25          30

gat gtt aat gga aca cat ttt att gct aca aaa gag aaa gaa ata tta      144
Asp Val Asn Gly Thr His Phe Ile Ala Thr Lys Glu Lys Glu Ile Leu
          35          40          45

```

-continued

tat gat tca ctt gat tta agg gct cgt gga aaa ata ttt gaa ata act	192
Tyr Asp Ser Leu Asp Leu Arg Ala Arg Gly Lys Ile Phe Glu Ile Thr	
50 55 60	

tca aag cga atg ttt aag ctt	213
Ser Lys Arg Met Phe Lys Leu	
65 70	

<210> SEQ ID NO 56
 <211> LENGTH: 71
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 56

Val Asn Tyr Tyr Arg Ile Arg Thr Ser Val Arg Tyr Glu Ser Phe Gly	
1 5 10 15	
Tyr Phe Ala Ala Ala Asn Glu Phe Glu Ile Ser Glu Val Lys Ile Ala	
20 25 30	
Asp Val Asn Gly Thr His Phe Ile Ala Thr Lys Glu Lys Glu Ile Leu	
35 40 45	
Tyr Asp Ser Leu Asp Leu Arg Ala Arg Gly Lys Ile Phe Glu Ile Thr	
50 55 60	
Ser Lys Arg Met Phe Lys Leu	
65 70	

<210> SEQ ID NO 57
 <211> LENGTH: 8762
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 57

gagagtgctg ttgatggggt tagcaagtgg ttagaagaga tgataaaagc tgctaaggag	60
gctgctacaa aggggtgtac tgggtgggtg agcgaaga ttggggatgt tgggtgctgct	120
aataatcagg gtgctgtagc tgataaggac agtgtaagg ggattgcgaa ggggataaag	180
gggattggtg atgctgctgg gaaggctttt ggtaaggatg gtaatgcgct gacagggtga	240
aaagaagttg ctgatgaggc tggggctaac gaggatgcgg ggaagttggt tgctggtaat	300
gctggtaatg ctgctgctgc tgacattgcg aaggcggctg gtgctgttac tgcggttagt	360
ggggagcaga tactgaaagc tattgttgat ggtgctgggt gtgcggctca agatggtaaa	420
aaggctgcgg aggctaagaa tccgattgca gctgcgattg gggctgatgc tgctgggtgcg	480
gattttgggtg atgatatgaa gaagagtgat aagattgctg cggctattgt tttgaggggg	540
gtggctaaga gtggaaagt ttgctgttgc aatgctgcta agaaggagag tgtgaagagt	600
gctgtggaga gtgctgttga tgaggttagc aagtggttag aagagatgat aaaagctgct	660
ggtggggctg ctaagggtgg tactgggtgg aataacgaaa agattgggga ttctgataat	720
aataagggtg ctgtagctga taaggacagt gtaagggga ttgcgaagg gataaagggg	780
attgttgatg ctgctgggaa ggcttttgg aaggatggta atgcgctgaa ggatgttgca	840
aaagttgctg atgatgcggc tggggctaac gcgaatgcag ggaagttggt tgctggtaat	900
gctgctgggtg gtgcccctga tgctgatgat gctaacattg cgaaggcggc tgggtgctggt	960
agtgcggtta gtggggagca gatactgaaa gctattgttg atgctgctgg tgctgctgct	1020
aatcaggatg gtaagaaggc tgccgatgct aagaatccga ttgcagctgc gattgggact	1080
aatgatgatg gggcggagtt taaggatgga atgaagaaga gtgataatat tgctgcagct	1140
attgttttga ggggggtggc taagggtgga aagtttctg ttgctaagtc tgctaagatg	1200

- continued

agtaaggcga	gtgtgaagag	tgctgtggag	agtgctgttg	atgaggttag	caagtgggta	1260
gaagagatga	taacagctgc	tggtgaggct	gctacaaagg	gtggtgatgc	tggtgggggt	1320
gctgataaga	ttggggatgt	tggtgctgct	aataatgggtg	ctgtagctga	tgcgagcagt	1380
gttaaggaga	ttgcgaagg	gataaagggg	attggtgatg	ctgctgggaa	ggcttttggc	1440
aaggatggta	atgctgctgaa	ggatggttgc	gaagttgctg	atgataagaa	ggaggcgggg	1500
aagttgtttg	ctggtaatgc	tggtgggtgct	gttctgctg	ctgctgcat	tggaaggcg	1560
gctggtgctg	ttactgcggt	tagtggggag	cagatactga	aagctattgt	tgatgctgct	1620
ggtggtgctg	atcaggcggg	taagaaggct	gatgctgctg	agaatccgat	tgcagctgctg	1680
attggggctg	atgctgctgg	tgctgggtgctg	gattttggta	atgatatgaa	gaagagaaat	1740
gataagattg	ttgcggctat	tgttttgagg	gggtggctg	aggatggaaa	gtttgctgct	1800
gctgctaata	atgataatag	taaggcagctg	gtgaagagtg	ctgtggagag	tgctggtgat	1860
gaggttagca	agtgggttaga	agagatgata	acagctgctg	atggggctgc	taaagggtgg	1920
actggtggta	atagcgaaaa	gattggggat	gctggtgata	ataataatgg	tgctgtagct	1980
gatgagaaca	gtgttaagga	gattgcaaag	gggataaagg	ggattgttgc	ggctgctggg	2040
aaggcttttg	gcaaggatgg	caaggatgg	gatgctgctg	aggatgttga	aacagttgct	2100
gctgagaatg	aggctaacaa	ggatgctggg	aagttgtttg	ctgggtgctaa	tggtaatgct	2160
ggtgctgctg	ttggtgacat	tgcgaaggcg	gctgctgctg	ttactgcggt	tagtggggag	2220
cagatactaa	aagctattgt	tgatgctgct	ggtgatgctg	atcaggcggg	taagaaggct	2280
gctgaggcta	agaatccgat	tgcagctgctg	attggggctg	atgctgctga	taatgcggcg	2340
gctgttggtg	aggatgagat	gaagaagag	gataagattg	ctgcagctat	tgttttgagg	2400
gggtggctg	aggatggaaa	gtttgctgct	gctaagctg	atgatgataa	gaaggcagct	2460
gtgaagagtg	ctgtggagag	tgctgtggat	gaggttagca	agtgggttaga	agagatgata	2520
acagctgcta	aggaggctgc	tacaaagggt	ggtactgggtg	gtaataacga	aaagattgga	2580
gattctgatg	ctaataatgg	tgcgaaggct	gatgctgctg	gtgttaatgg	gattgcgaat	2640
gggataaagg	ggattgttga	tgctgctggg	aaggcttttg	gcaaggaggg	tagtgcgctg	2700
aaggatgtta	aaacagttgc	tgctgagaat	gaggctaaca	aggatgctgg	gaagttgttt	2760
gctggtaaga	atggtaatgc	tgatgctgct	gatgctgctg	acattgcgaa	ggcggctgg	2820
gctgttagtg	cggttagtg	ggagcagata	ctgaaagcta	ttggtgatgg	tgctgggtgat	2880
gcagctaata	aggcgggtaa	aaaggctgct	gaggctaaga	atccgattgc	ggctgctgatt	2940
gggactaatg	aagctggggc	ggagtttgg	gatgatatga	agaagagaaa	tgataagatt	3000
gctgctgata	atagtaaggc	gagtgtgaag	agtgctgttg	atgaggttag	caagtgggta	3120
gaagagatga	taaaggctgc	tggtgaggct	gctacaaagg	gtggtgatgc	tggtgggggt	3180
gctgataaga	ttggggatgc	tggtgataag	ggtgctgtag	ctgatgctgag	cagtgttaag	3240
gagattgcca	atgggataaa	ggggattggt	gatgctgctg	ggaaggcttt	tggaaggag	3300
gtagtgctg	tgaaggatgt	taaaacagtt	gctgctgaga	atgaggctaa	caaggatgctg	3360
gggaagttgt	ttgctggtaa	tgctggtaat	ggtgctgctg	atgacattgc	gaaggcggct	3420
gctgctgtta	ctgcggtag	tggggagcag	atactgaaag	ctattgttga	tgctgctgg	3480
gataaggcta	atcaggatgg	taaaaaggct	gctgatgctg	agaatccgat	tgcggctgctg	3540
attggggctg	ctgatgctg	tgctgctggc	gctttaatg	agaatgatat	gaagaagag	3600

-continued

gataagattg	ctgcagctat	tgttttgagg	ggggtggcta	aggatggaaa	gtttgctgct	3660
gctgatgctg	atgctaataa	tagtaaggcg	agcgtgaaga	gtgctgttgg	tgaggttagc	3720
aagtggttag	aagagatgat	aaaagctgct	ggtgaggctg	caaaagttgg	tggtactggt	3780
ggtagcggaa	agattgggga	tgctgataat	aataaggggtg	ctgtagctga	tgcgagcagt	3840
gttaatggga	ttgcgaatgg	gataaagggg	attgttgatg	ctgctgggaa	ggcttttggt	3900
aaggatgggtg	cgctggcagg	tgttgccagct	gctgctgaga	atgatgataa	gaaggatgcg	3960
gggaagttgt	ttgctggtaa	gaatgggtgg	gctgggtgctg	ctgatgcgat	tggaaggcg	4020
gctgctgctg	ttactgcggt	tagtggggag	cagatactga	aagctattgt	tgatgctgct	4080
ggtgctgcag	ctaatcaggc	gggtaaaaag	gctgcggatg	ctaagaatcc	gattgcccgt	4140
gcgattggga	ctgctgatga	tggggcggag	ttaaggatg	atatgaagaa	gagtgataat	4200
attgctgcgg	ctattgtttt	gaggggggtg	gctaaggatg	gaaagtttgc	tgttgctaata	4260
gctgatgata	ataaggcag	tgtgaagagt	gctgtggaga	gtgctgttga	tgaggttagc	4320
aagtggttag	aagagatgat	aacagctgct	ggtgaggctg	caaaagttgg	tgctgggtgg	4380
ggtgctgata	agattgggga	tgctgctaata	aatcagggtg	cgaaggctga	tgagagcagt	4440
gttaatggaa	ttgcaaagg	gataaagggg	attgttgatg	ctgctgggaa	ggcttttggc	4500
aaggagggtg	gtgcgctgaa	ggatgttgca	aaagttgctg	atgatgataa	caaggatgcg	4560
gggaagttgt	ttgctggtaa	tgctgggtgg	ggtgctgggtg	ctgatattgc	gaaggcggct	4620
gctgctgtta	ctgcggttag	tggggagcag	atactgaaag	ctattgttga	tgctgctggt	4680
gctgcggatc	aggcgggtgc	agctgctgg	gctgctaaga	atccgattgc	ggctgcgatt	4740
gggctgatg	ctggtgctgc	ggaggagttt	aaggatgaga	tgaagaagag	tgataagatt	4800
gctgcggcta	ttgttttgag	gggggtggct	aagggtggaa	agtttgctgt	tgctgctaata	4860
gatgctgcaa	atgtgaagag	tgctgtggag	agtgctgttg	gtgaggttag	cgcatggtta	4920
gaagagatga	taacagctgc	tagtgaggct	gctacaaagg	gtggtactgg	tggtactggt	4980
ggtgatagtg	aaaagattgg	ggattctgat	gctaataatg	gtgctgtagc	tgatgcgagc	5040
agtgttaagg	agattgcgaa	ggggataaag	gggattgttg	atgctgctgg	gaaggctttt	5100
ggtaaggatg	gtaatgcgct	gaaggatggt	gcagaagttg	ctgatgatga	ggctaaccgc	5160
gatgcgggga	agttgtttgc	tggtaatgct	ggtaatgctg	ctgctgctga	cgttgcgaag	5220
gctgctgggtg	ctgttactgc	ggttagtggg	gagcagatac	tgaaagctat	tgttgatgct	5280
gctggtgctg	cggatcaggc	gggtgcaaag	gctgatgcgg	ctaagaatcc	gattgcagct	5340
gcgattggga	ctaatgaagc	tggggcggcg	ttaaggatg	gaatgaagaa	gagaaatgat	5400
aatattgctg	cggctattgt	tttgaggggg	gtggctaaga	gtgaaagt	tgctgttgct	5460
gctgctgatg	ctggtaaggc	gagagtgtga	agagtgctgt	ggagagtgct	gttgatgagg	5520
ttagcaagtg	gttagaagag	atgataacag	ctgctagtga	ggctgcaaaa	gttggtgctg	5580
gtgggtgatga	taagattggg	gattctgcta	ataatgggtg	tgtagctgat	gcgggcagtg	5640
ttaagggaa	tgcaagggg	ataaagggga	ttgttgatgc	tgctgggaag	gcttttggtg	5700
aggagggtga	tgcgctgaag	gatggtgcaa	aagttgctga	tgagaatggg	gataacaagg	5760
atgcggggaa	gttgtttgct	ggtgagaatg	gtaatgctgg	tggtgctgct	gatgctgaca	5820
ttgcgaaggc	ggctgctgct	gttactgcgg	ttagtgggga	gcagatactg	aaagctattg	5880
ttgaggctgc	tggtgctggt	gatgcagcta	atcaggcggg	taagaaggct	gatgaggcta	5940

-continued

agaatccgat	tgcggctgcg	attgggactg	atgatgctgg	ggcggcgttt	ggtcaggatg	6000
atatgaagaa	gagaaatgat	aatattgctg	cggctattgt	tttgaggggg	gtggctaagg	6060
gtggaagtt	tgctgttgct	aatgctgcta	atgatagtaa	ggcggagtgtg	aagagtgctg	6120
tggagagtgc	tgttgatgag	gttagcaagt	ggttagaaga	gataataaca	gctactggga	6180
aggcttttgg	taaggatggt	aatgctgctg	cagggtgtgc	aaaagttgct	gatgatgagg	6240
ctaacgcgga	tgcggggaag	ttgtttgctg	gtgagaatgg	taatgctggt	gctgctgcga	6300
ttgggaaggc	ggctgctgct	gttactgctg	ttagtgggga	gcagatactg	aaagctattg	6360
ttgatgctgc	tgggtggtgcg	gctcagggtg	gtgctggtgc	tgggtgcggct	acgaatccga	6420
ttgcagctgc	gattggggct	gctgggtgatg	gtgcggatth	tggtaaggat	gagatgaaga	6480
agagaaatga	taagattgct	gctggctattg	ttttgagggg	gggtggctaag	gatggaaagt	6540
ttgctgctgc	tgctaattgat	agtaaggcga	gtgtgaagag	tgctgtggag	agtgctgttg	6600
atgaggttag	caagtgggta	gaagagatga	taacagctgc	tgatgctgct	gctgctaaag	6660
ttggcgatgc	tgggtggtggt	gctgataaga	ttggggatgt	tgggtgctgct	aataaggggtg	6720
cgaaggctga	tgcgagcagt	gttaaggaga	ttgcgaaggg	gataaagggg	attggtgatg	6780
ctgctgggaa	ggcttttggg	ggtgatgctg	tgaaggatgt	taaagctgct	ggtgatgata	6840
acaaggaggc	agggaaagtg	tttgctgggtg	ctaattgtaa	tgctgggtgct	aatgctgctg	6900
ctgctgatga	cattgcgaag	gctggctgggtg	ctgttagtgc	ggtagtggg	gagcagatac	6960
tgaaagctat	tgttgaggcg	gctgggtgctg	cggatcaggc	gggtgtaaag	gctgaggagg	7020
ctaagaatcc	gattgcagct	gctgattggga	ctgatgatgc	tgggtgcggcg	gagtttgggtg	7080
agaatgatat	gaagaagaat	gataaatattg	ctgctggctat	tgttttgagg	ggggtggcta	7140
agagtggaaa	gtttgcctgct	aatgctaattg	atgctggtaa	gaaggagagt	gtgaagagtg	7200
ctgtggatga	ggctagcaag	tggtagaag	agatgataac	agctgctggt	gaggctgcta	7260
caaagggtgg	tactggtgaa	gctagcgaag	agattgggga	tgttgggtgat	aataatcatg	7320
gtgctgtagc	tgatgcggac	agtgttaagg	ggattgcgaa	ggggataaag	gggattgttg	7380
atgctgctgg	gaaggctttt	ggtaaggatg	gtgcctgaa	ggatgttgca	gctgctgctg	7440
gtgatgaggc	taacaaggat	gctggggaagt	tgtttgctgg	tcaggatggt	ggtgggtgctg	7500
atggtgacat	tgcgaaggcg	gctgctgctg	ttactgcggg	tagtggggag	cagatactga	7560
aagctattgt	tgaggctgct	ggtgataagg	ctaactcagg	gggtgtaaag	gctgctgggtg	7620
cggctacgaa	tccgattgca	gctgctgattg	ggactgatga	tgataatgctg	gctggctttg	7680
ataaggatga	gatgaagaag	agtaatgata	agattgctgc	ggctattggt	ttgagggggg	7740
tggctaagga	tggaaagttt	gctgctaattg	ctaactgata	tagtaaggcg	agtgtgaaga	7800
gtgctgtgga	tgaggttagc	aagtggttag	aagagatgat	aacagctgct	agtgatgctg	7860
ctacaaaggg	tggtagctggt	gaagctagcg	aaaagattgg	ggattctgat	gctaataagg	7920
gtgctgggtgc	tggggcggcg	tttgggtgaga	atgatatgaa	gaagagaaat	gataaatattg	7980
ctgcagctat	tgttttgagg	ggggtggcta	aggatggaaa	gtttgctggt	aaggaggatt	8040
atgaactca	gctttatagg	ggaacagcaa	ttccttagaa	aatgattaa	aagcttaact	8100
tgcactgggt	cttgcttaaa	ttttattcct	ttgttattat	ttatcaatta	aattcacttc	8160
ggtttgcttt	taaattaatt	ctggtatact	atgtatacta	gatacaciaa	ttaaggagaa	8220
gtgaaatgga	aaaaatagaa	aaatttaaaa	acaaatgtca	acataaacta	caacataaac	8280
taatcgtatt	agtatcaaca	ctttgctata	taaacaataa	aaataaaaaa	tattcaciaa	8340

-continued

```

gcaacatcct ttattatattt aatgaaaatt taaaaagaaa tgggcaaacc cctattaataa 8400
taaaaaacatt acaaaactat ctttataaac tggaaaaaga atttgaagta acaactaatt 8460
attataaaca cttggggggtt aattgtggaa ccgaaattta ctataaactt aaatatcaaa 8520
aacaaaaatg ctatcataaa ataaaccaat attttaaaaa gaaaaaagaa attaaattta 8580
acttaagagt aagtgcattt ttttaataaaa aacctcaaa aaaaggaggat gtagaattaa 8640
aggaatgtaa taataataat aataataaag agaaagaaac atcccaaaaa attgaaattt 8700
tacaacaaca agtctatgcc aaaaaatgta aatttttgac aaactactat actaaaattt 8760
ta 8762

```

```

<210> SEQ ID NO 58
<211> LENGTH: 606
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(606)

```

<400> SEQUENCE: 58

```

gag agt gct gtt gat ggg gtt agc aag tgg tta gaa gag atg ata aaa 48
Glu Ser Ala Val Asp Gly Val Ser Lys Trp Leu Glu Glu Met Ile Lys
1 5 10 15
gct gct aag gag gct gct aca aag ggt ggt act ggt ggt ggt agc gaa 96
Ala Ala Lys Glu Ala Ala Thr Lys Gly Gly Thr Gly Gly Gly Ser Glu
20 25 30
aag att ggg gat gtt ggt gct gct aat aat cag ggt gct gta gct gat 144
Lys Ile Gly Asp Val Gly Ala Ala Asn Asn Gln Gly Ala Val Ala Asp
35 40 45
aag gac agt gtt aag ggg att gcg aag ggg ata aag ggg att gtt gat 192
Lys Asp Ser Val Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp
50 55 60
gct gct ggg aag gct ttt ggt aag gat ggt aat gcg ctg aca ggt gta 240
Ala Ala Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Thr Gly Val
65 70 75 80
aaa gaa gtt gct gat gag gct ggg gct aac gag gat gcg ggg aag ttg 288
Lys Glu Val Ala Asp Glu Ala Gly Ala Asn Glu Asp Ala Gly Lys Leu
85 90 95
ttt gct ggt aat gct ggt aat gct gct gct gct gac att gcg aag gcg 336
Phe Ala Gly Asn Ala Gly Asn Ala Ala Ala Asp Ile Ala Lys Ala
100 105 110
gct ggt gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att 384
Ala Gly Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile
115 120 125
gct gat ggt gct ggt ggt gcg gct caa gat ggt aaa aag gct gcg gag 432
Val Asp Gly Ala Gly Gly Ala Ala Gln Asp Gly Lys Lys Ala Ala Glu
130 135 140
gct aag aat ccg att gca gct gcg att ggg gct gat gct gct ggt gcg 480
Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asp Ala Ala Gly Ala
145 150 155 160
gat ttt ggt gat gat atg aag aag agt gat aag att gct gcg gct att 528
Asp Phe Gly Asp Asp Met Lys Lys Ser Asp Lys Ile Ala Ala Ala Ile
165 170 175
gct ttg agg ggg gtg gct aag agt gga aag ttt gct gtt gct aat gct 576
Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala Val Ala Asn Ala
180 185 190
gct aag aag gag agt gtg aag agt gct gtg 606
Ala Lys Lys Glu Ser Val Lys Ser Ala Val
195 200

```

-continued

<210> SEQ ID NO 59
 <211> LENGTH: 202
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 59

Glu Ser Ala Val Asp Gly Val Ser Lys Trp Leu Glu Glu Met Ile Lys
 1 5 10 15
 Ala Ala Lys Glu Ala Ala Thr Lys Gly Gly Thr Gly Gly Gly Ser Glu
 20 25 30
 Lys Ile Gly Asp Val Gly Ala Ala Asn Asn Gln Gly Ala Val Ala Asp
 35 40 45
 Lys Asp Ser Val Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp
 50 55 60
 Ala Ala Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Thr Gly Val
 65 70 75 80
 Lys Glu Val Ala Asp Glu Ala Gly Ala Asn Glu Asp Ala Gly Lys Leu
 85 90 95
 Phe Ala Gly Asn Ala Gly Asn Ala Ala Ala Asp Ile Ala Lys Ala
 100 105 110
 Ala Gly Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile
 115 120 125
 Val Asp Gly Ala Gly Gly Ala Ala Gln Asp Gly Lys Lys Ala Ala Glu
 130 135 140
 Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asp Ala Ala Gly Ala
 145 150 155 160
 Asp Phe Gly Asp Asp Met Lys Lys Ser Asp Lys Ile Ala Ala Ala Ile
 165 170 175
 Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala Val Ala Asn Ala
 180 185 190
 Ala Lys Lys Glu Ser Val Lys Ser Ala Val
 195 200

<210> SEQ ID NO 60
 <211> LENGTH: 621
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(621)

<400> SEQUENCE: 60

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aaa 48
 Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys
 1 5 10 15
 gct gct ggt ggg gct gct aag ggt ggt act ggt ggt aat aac gaa aag 96
 Ala Ala Gly Gly Ala Ala Lys Gly Gly Thr Gly Gly Asn Asn Glu Lys
 20 25 30
 att ggg gat tct gat aat aat aag ggt gct gta gct gat aag gac agt 144
 Ile Gly Asp Ser Asp Asn Asn Lys Gly Ala Val Ala Asp Lys Asp Ser
 35 40 45
 gtt aag ggg att gcg aag ggg ata aag ggg att gtt gat gct gct ggg 192
 Val Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly
 50 55 60
 aag gct ttt ggt aag gat ggt aat gcg ctg aag gat gtt gca aaa gtt 240
 Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Lys Asp Val Ala Lys Val
 65 70 75 80

-continued

gct gat gat gcg gct ggg gct aac gcg aat gca ggg aag ttg ttt gct	288
Ala Asp Asp Ala Ala Gly Ala Asn Ala Asn Ala Gly Lys Leu Phe Ala	
85 90 95	
ggt aat gct gct ggt ggt gcc gct gat gct gat gat gct aac att gcg	336
Gly Asn Ala Ala Gly Gly Ala Ala Asp Ala Asp Asp Ala Asn Ile Ala	
100 105 110	
aag gcg gct ggt gct gtt agt gcg gtt agt ggg gag cag ata ctg aaa	384
Lys Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys	
115 120 125	
gct att gtt gat gct gct ggt gct gct gct aat cag gat ggt aag aag	432
Ala Ile Val Asp Ala Ala Gly Ala Ala Ala Asn Gln Asp Gly Lys Lys	
130 135 140	
gct gcg gat gct aag aat ccg att gca gct gcg att ggg act aat gat	480
Ala Ala Asp Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Asp	
145 150 155 160	
gat ggg gcg gag ttt aag gat gga atg aag aag agt gat aat att gct	528
Asp Gly Ala Glu Phe Lys Asp Gly Met Lys Lys Ser Asp Asn Ile Ala	
165 170 175	
gca gct att gtt ttg agg ggg gtg gct aag ggt gga aag ttt gct gtt	576
Ala Ala Ile Val Leu Arg Gly Val Ala Lys Gly Gly Lys Phe Ala Val	
180 185 190	
gct aat gct gct aat gat agt aag gcg agt gtg aag agt gct gtg	621
Ala Asn Ala Ala Asn Asp Ser Lys Ala Ser Val Lys Ser Ala Val	
195 200 205	

<210> SEQ ID NO 61

<211> LENGTH: 207

<212> TYPE: PRT

<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 61

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys	
1 5 10 15	
Ala Ala Gly Gly Ala Ala Lys Gly Gly Thr Gly Gly Asn Asn Glu Lys	
20 25 30	
Ile Gly Asp Ser Asp Asn Asn Lys Gly Ala Val Ala Asp Lys Asp Ser	
35 40 45	
Val Lys Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly	
50 55 60	
Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Lys Asp Val Ala Lys Val	
65 70 75 80	
Ala Asp Asp Ala Ala Gly Ala Asn Ala Asn Ala Gly Lys Leu Phe Ala	
85 90 95	
Gly Asn Ala Ala Gly Gly Ala Ala Asp Ala Asp Asp Ala Asn Ile Ala	
100 105 110	
Lys Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys	
115 120 125	
Ala Ile Val Asp Ala Ala Gly Ala Ala Ala Asn Gln Asp Gly Lys Lys	
130 135 140	
Ala Ala Asp Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Asp	
145 150 155 160	
Asp Gly Ala Glu Phe Lys Asp Gly Met Lys Lys Ser Asp Asn Ile Ala	
165 170 175	
Ala Ala Ile Val Leu Arg Gly Val Ala Lys Gly Gly Lys Phe Ala Val	
180 185 190	
Ala Asn Ala Ala Asn Asp Ser Lys Ala Ser Val Lys Ser Ala Val	
195 200 205	

-continued

```

<210> SEQ ID NO 62
<211> LENGTH: 618
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(618)

<400> SEQUENCE: 62

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aca      48
Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1                               5                10                15

gct gct ggt gag gct gct aca aag ggt ggt gat gct ggt ggt ggt gct      96
Ala Ala Gly Glu Ala Ala Thr Lys Gly Gly Asp Ala Gly Gly Gly Ala
                20                25                30

gat aag att ggg gat gtt ggt gct gct aat aat ggt gct gta gct gat      144
Asp Lys Ile Gly Asp Val Gly Ala Ala Asn Asn Gly Ala Val Ala Asp
                35                40                45

gcg agc agt gtt aag gag att gcg aag ggg ata aag ggg att gtt gat      192
Ala Ser Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile Val Asp
                50                55                60

gct gct ggg aag gct ttt ggc aag gat ggt aat gcg ctg aag gat gtt      240
Ala Ala Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Lys Asp Val
65                70                75                80

gca gaa gtt gct gat gat aag aag gag gcg ggg aag ttg ttt gct ggt      288
Ala Glu Val Ala Asp Asp Lys Lys Glu Ala Gly Lys Leu Phe Ala Gly
                85                90                95

aat gct ggt ggt gct gtt gct gat gct gct gcg att ggg aag gcg gct      336
Asn Ala Gly Gly Ala Val Ala Asp Ala Ala Ile Gly Lys Ala Ala
                100               105               110

ggt gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt      384
Gly Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
                115               120               125

gat gct gct ggt ggt gcg gat cag gcg ggt aag aag gct gat gcg gct      432
Asp Ala Ala Gly Gly Ala Asp Gln Ala Gly Lys Lys Ala Asp Ala Ala
                130               135               140

aag aat ccg att gca gct gcg att ggg gct gat gct gct ggt gct ggt      480
Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asp Ala Ala Gly Ala Gly
145                150                155                160

gcg gat ttt ggt aat gat atg aag aag aga aat gat aag att gtt gcg      528
Ala Asp Phe Gly Asn Asp Met Lys Lys Arg Asn Asp Lys Ile Val Ala
                165               170               175

gct att gtt ttg agg ggg gtg gct aag gat gga aag ttt gct gct gct      576
Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala
                180               185               190

gct aat gat gat aat agt aag gcg agt gtg aag agt gct gtg      618
Ala Asn Asp Asp Asn Ser Lys Ala Ser Val Lys Ser Ala Val
                195                200                205

```

```

<210> SEQ ID NO 63
<211> LENGTH: 206
<212> TYPE: PRT
<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 63

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1                               5                10                15

Ala Ala Gly Glu Ala Ala Thr Lys Gly Gly Asp Ala Gly Gly Gly Ala
                20                25                30

Asp Lys Ile Gly Asp Val Gly Ala Ala Asn Asn Gly Ala Val Ala Asp
                35                40                45

```

-continued

Ala Ser Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile Val Asp
 50 55 60
 Ala Ala Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Lys Asp Val
 65 70 75 80
 Ala Glu Val Ala Asp Asp Lys Lys Glu Ala Gly Lys Leu Phe Ala Gly
 85 90 95
 Asn Ala Gly Gly Ala Val Ala Asp Ala Ala Ala Ile Gly Lys Ala Ala
 100 105 110
 Gly Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 115 120 125
 Asp Ala Ala Gly Gly Ala Asp Gln Ala Gly Lys Lys Ala Asp Ala Ala
 130 135 140
 Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asp Ala Ala Gly Ala Gly
 145 150 155 160
 Ala Asp Phe Gly Asn Asp Met Lys Lys Arg Asn Asp Lys Ile Val Ala
 165 170 175
 Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala
 180 185 190
 Ala Asn Asp Asp Asn Ser Lys Ala Ser Val Lys Ser Ala Val
 195 200 205

<210> SEQ ID NO 64
 <211> LENGTH: 630
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(630)

<400> SEQUENCE: 64

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aca 48
 Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
 1 5 10 15
 gct gct gat ggg gct gct aaa ggt ggt act ggt ggt aat agc gaa aag 96
 Ala Ala Asp Gly Ala Ala Lys Gly Gly Thr Gly Gly Asn Ser Glu Lys
 20 25 30
 att ggg gat gct ggt gat aat aat aat ggt gct gta gct gat gag aac 144
 Ile Gly Asp Ala Gly Asp Asn Asn Asn Gly Ala Val Ala Asp Glu Asn
 35 40 45
 agt gtt aag gag att gca aag ggg ata aag ggg att gtt gcg gct gct 192
 Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile Val Ala Ala Ala
 50 55 60
 ggg aag gct ttt ggc aag gat ggc aag gat ggt gat gcg ctg aag gat 240
 Gly Lys Ala Phe Gly Lys Asp Gly Lys Asp Gly Asp Ala Leu Lys Asp
 65 70 75 80
 gtt gaa aca gtt gct gct gag aat gag gct aac aag gat gcg ggg aag 288
 Val Glu Thr Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys
 85 90 95
 ttg ttt gct ggt gct aat ggt aat gct ggt gct gct gtt ggt gac att 336
 Leu Phe Ala Gly Ala Asn Gly Asn Ala Gly Ala Ala Val Gly Asp Ile
 100 105 110
 gcg aag gcg gct gct gct gtt act gcg gtt agt ggg gag cag ata cta 384
 Ala Lys Ala Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu
 115 120 125
 aaa gct att gtt gat gct gct ggt gat gcg gat cag gcg ggt aag aag 432
 Lys Ala Ile Val Asp Ala Ala Gly Asp Ala Asp Gln Ala Gly Lys Lys
 130 135 140
 gct gct gag gct aag aat ccg att gca gct gcg att ggg gct aat gct 480

-continued

Ala Ala Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asn Ala	
145	150 155 160
gct gat aat gcg gcg gcg ttt ggt aag gat gag atg aag aag agt gat	528
Ala Asp Asn Ala Ala Ala Phe Gly Lys Asp Glu Met Lys Lys Ser Asp	
	165 170 175
aag att gct gca gct att gtt ttg agg ggg gtg gct aag gat gga aag	576
Lys Ile Ala Ala Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys	
	180 185 190
ttt gct gtt gct aat gct aat gat gat aag aag gcg agt gtg aag agt	624
Phe Ala Val Ala Asn Ala Asn Asp Asp Lys Lys Ala Ser Val Lys Ser	
	195 200 205
gct gtg	630
Ala Val	
	210

<210> SEQ ID NO 65
 <211> LENGTH: 210
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 65

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr	
1	5 10 15
Ala Ala Asp Gly Ala Ala Lys Gly Gly Thr Gly Gly Asn Ser Glu Lys	
	20 25 30
Ile Gly Asp Ala Gly Asp Asn Asn Asn Gly Ala Val Ala Asp Glu Asn	
	35 40 45
Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile Val Ala Ala Ala	
	50 55 60
Gly Lys Ala Phe Gly Lys Asp Gly Lys Asp Gly Asp Ala Leu Lys Asp	
65	70 75 80
Val Glu Thr Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys	
	85 90 95
Leu Phe Ala Gly Ala Asn Gly Asn Ala Gly Ala Ala Val Gly Asp Ile	
	100 105 110
Ala Lys Ala Ala Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu	
	115 120 125
Lys Ala Ile Val Asp Ala Ala Gly Asp Ala Asp Gln Ala Gly Lys Lys	
	130 135 140
Ala Ala Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Asn Ala	
145	150 155 160
Ala Asp Asn Ala Ala Ala Phe Gly Lys Asp Glu Met Lys Lys Ser Asp	
	165 170 175
Lys Ile Ala Ala Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys	
	180 185 190
Phe Ala Val Ala Asn Ala Asn Asp Asp Lys Lys Ala Ser Val Lys Ser	
	195 200 205
Ala Val	
	210

<210> SEQ ID NO 66
 <211> LENGTH: 612
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii

<220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(612)

<400> SEQUENCE: 66

-continued

```

gag agt gct gtg gat gag gtt agc aag tgg tta gaa gag atg ata aca      48
Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1          5          10          15

gct gct aag gag gct gct aca aag ggt ggt act ggt ggt aat aac gaa      96
Ala Ala Lys Glu Ala Ala Thr Lys Gly Gly Thr Gly Gly Asn Asn Glu
20          25          30

aag att gga gat tct gat gct aat aat ggt gcg aag gct gat gcg agc      144
Lys Ile Gly Asp Ser Asp Ala Asn Asn Gly Ala Lys Ala Asp Ala Ser
35          40          45

agt gtt aat ggg att gcg aat ggg ata aag ggg att gtt gat gct gct      192
Ser Val Asn Gly Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala
50          55          60

ggg aag gct ttt ggc aag gag ggt agt gcg ctg aag gat gtt aaa aca      240
Gly Lys Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr
65          70          75          80

gtt gct gct gag aat gag gct aac aag gat gcg ggg aag ttg ttt gct      288
Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala
85          90          95

ggt aag aat ggt aat gct gat gct gct gat gct gct gac att gcg aag      336
Gly Lys Asn Gly Asn Ala Asp Ala Ala Asp Ala Ala Asp Ile Ala Lys
100         105         110

gcg gct ggt gct gtt agt gcg gtt agt ggg gag cag ata ctg aaa gct      384
Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys Ala
115         120         125

att gtt gat ggt gct ggt gat gca gct aat cag gcg ggt aaa aag gct      432
Ile Val Asp Gly Ala Gly Asp Ala Ala Asn Gln Ala Gly Lys Lys Ala
130         135         140

gct gag gct aag aat ccg att gcg gct gcg att ggg act aat gaa gct      480
Ala Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Glu Ala
145         150         155         160

ggg gcg gag ttt ggt gat gat atg aag aag aga aat gat aag att gct      528
Gly Ala Glu Phe Gly Asp Asp Met Lys Lys Arg Asn Asp Lys Ile Ala
165         170         175

gcg gct att gtt ttg agg ggg gtg gct aag gat gga aag ttt gct gtt      576
Ala Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Val
180         185         190

gct aat gct gct gct gat aat agt aag gcg agt gtg      612
Ala Asn Ala Ala Ala Asp Asn Ser Lys Ala Ser Val
195         200

```

```

<210> SEQ ID NO 67
<211> LENGTH: 204
<212> TYPE: PRT
<213> ORGANISM: Borrelia afzelii

```

```

<400> SEQUENCE: 67

```

```

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1          5          10          15

Ala Ala Lys Glu Ala Ala Thr Lys Gly Gly Thr Gly Gly Asn Asn Glu
20          25          30

Lys Ile Gly Asp Ser Asp Ala Asn Asn Gly Ala Lys Ala Asp Ala Ser
35          40          45

Ser Val Asn Gly Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala
50          55          60

Gly Lys Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr
65          70          75          80

Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala
85          90          95

```


-continued

Gly Lys Asn Gly Asn Ala Asp Ala Ala Asp Ala Ala Asp Ile Ala Lys
 100 105 110

Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys Ala
 115 120 125

Ile Val Asp Gly Ala Gly Asp Ala Ala Asn Gln Ala Gly Lys Lys Ala
 130 135 140

Ala Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Glu Ala
 145 150 155 160

Gly Ala Glu Phe Gly Asp Asp Met Lys Lys Arg Asn Asp Lys Ile Ala
 165 170 175

Ala Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Val
 180 185 190

Ala Asn Ala Ala Ala Asp Asn Ser Lys Ala Ser Val
 195 200

<210> SEQ ID NO 68
 <211> LENGTH: 609
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(609)

<400> SEQUENCE: 68

aag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aag 48
 Lys Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys
 1 5 10 15

gct gct ggt gag gct gct aca aag ggt ggt gat gct ggt ggt ggt gct 96
 Ala Ala Gly Glu Ala Ala Thr Lys Gly Gly Asp Ala Gly Gly Gly Ala
 20 25 30

gat aag att ggg gat gct ggt gat aag ggt gct gta gct gat gcg agc 144
 Asp Lys Ile Gly Asp Ala Gly Asp Lys Gly Ala Val Ala Asp Ala Ser
 35 40 45

agt gtt aag gag att gcg aat ggg ata aag ggg att gtt gat gct gct 192
 Ser Val Lys Glu Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala
 50 55 60

ggg aag gct ttt ggc aag gag ggt agt gcg ctg aag gat gtt aaa aca 240
 Gly Lys Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr
 65 70 75 80

gtt gct gct gag aat gag gct aac aag gat gcg ggg aag ttg ttt gct 288
 Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala
 85 90 95

ggt aat gct ggt aat ggt gct gct gat gac att gcg aag gcg gct gct 336
 Gly Asn Ala Gly Asn Gly Ala Ala Asp Asp Ile Ala Lys Ala Ala Ala
 100 105 110

gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt gat 384
 Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp
 115 120 125

gct gct ggt gat aag gct aat cag gat ggt aaa aag gct gcg gat gct 432
 Ala Ala Gly Asp Lys Ala Asn Gln Asp Gly Lys Lys Ala Ala Asp Ala
 130 135 140

aag aat ccg att gcg gct gcg att ggg gct gct gat gct ggt gct gcg 480
 Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Ala Asp Ala Gly Ala Ala
 145 150 155 160

gcg gcg ttt aat gag aat gat atg aag aag agt gat aag att gct gca 528
 Ala Ala Phe Asn Glu Asn Asp Met Lys Lys Ser Asp Lys Ile Ala Ala
 165 170 175

gct att gtt ttg agg ggg gtg gct aag gat gga aag ttt gct gct gct 576
 Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala
 180 185 190

-continued

gat gct gat gct aat aat agt aag gcg agc gtg 609
 Asp Ala Asp Ala Asn Asn Ser Lys Ala Ser Val
 195 200

<210> SEQ ID NO 69
 <211> LENGTH: 203
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 69

Lys Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys
 1 5 10 15
 Ala Ala Gly Glu Ala Ala Thr Lys Gly Gly Asp Ala Gly Gly Gly Ala
 20 25 30
 Asp Lys Ile Gly Asp Ala Gly Asp Lys Gly Ala Val Ala Asp Ala Ser
 35 40 45
 Ser Val Lys Glu Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala
 50 55 60
 Gly Lys Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Lys Thr
 65 70 75 80
 Val Ala Ala Glu Asn Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala
 85 90 95
 Gly Asn Ala Gly Asn Gly Ala Ala Asp Asp Ile Ala Lys Ala Ala Ala
 100 105 110
 Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp
 115 120 125
 Ala Ala Gly Asp Lys Ala Asn Gln Asp Gly Lys Lys Ala Ala Asp Ala
 130 135 140
 Lys Asn Pro Ile Ala Ala Ala Ile Gly Ala Ala Asp Ala Gly Ala Ala
 145 150 155 160
 Ala Ala Phe Asn Glu Asn Asp Met Lys Lys Ser Asp Lys Ile Ala Ala
 165 170 175
 Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala
 180 185 190
 Asp Ala Asp Ala Asn Asn Ser Lys Ala Ser Val
 195 200

<210> SEQ ID NO 70
 <211> LENGTH: 600
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(600)

<400> SEQUENCE: 70

aag agt gct gtt ggt gag gtt agc aag tgg tta gaa gag atg ata aaa 48
 Lys Ser Ala Val Gly Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys
 1 5 10 15
 gct gct ggt gag gct gca aaa gtt ggt ggt act ggt ggt agc gaa aag 96
 Ala Ala Gly Glu Ala Ala Lys Val Gly Gly Thr Gly Gly Ser Glu Lys
 20 25 30
 att ggg gat gct gat aat aat aag ggt gct gta gct gat gcg agc agt 144
 Ile Gly Asp Ala Asp Asn Asn Lys Gly Ala Val Ala Asp Ala Ser Ser
 35 40 45
 gtt aat ggg att gcg aat ggg ata aag ggg att gtt gat gct gct ggg 192
 Val Asn Gly Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala Gly
 50 55 60

-continued

aag gct ttt ggt aag gat ggt gcg ctg gca ggt gtt gca gct gct gct	240
Lys Ala Phe Gly Lys Asp Gly Ala Leu Ala Gly Val Ala Ala Ala Ala	
65 70 75 80	
gag aat gat gat aag aag gat gcg ggg aag ttg ttt gct ggt aag aat	288
Glu Asn Asp Asp Lys Lys Asp Ala Gly Lys Leu Phe Ala Gly Lys Asn	
85 90 95	
ggt ggt gct ggt gct gct gat gcg att ggg aag gcg gct gct gct gtt	336
Gly Gly Ala Gly Ala Ala Asp Ala Ile Gly Lys Ala Ala Ala Ala Val	
100 105 110	
act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt gat gct gct	384
Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala	
115 120 125	
ggt gct gca gct aat cag gcg ggt aaa aag gct gcg gat gct aag aat	432
Gly Ala Ala Ala Asn Gln Ala Gly Lys Lys Ala Ala Asp Ala Lys Asn	
130 135 140	
ccg att gcg gct gcg att ggg act gct gat gat ggg gcg gag ttt aag	480
Pro Ile Ala Ala Ala Ile Gly Thr Ala Asp Asp Gly Ala Glu Phe Lys	
145 150 155 160	
gat gat atg aag aag agt gat aat att gct gcg gct att gtt ttg agg	528
Asp Asp Met Lys Lys Ser Asp Asn Ile Ala Ala Ala Ile Val Leu Arg	
165 170 175	
ggg gtg gct aag gat gga aag ttt gct gtt gct aat gct gat gat aat	576
Gly Val Ala Lys Asp Gly Lys Phe Ala Val Ala Asn Ala Asp Asp Asn	
180 185 190	
aag gcg agt gtg aag agt gct gtg	600
Lys Ala Ser Val Lys Ser Ala Val	
195 200	

<210> SEQ ID NO 71
 <211> LENGTH: 200
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 71

Lys Ser Ala Val Gly Glu Val Ser Lys Trp Leu Glu Glu Met Ile Lys	
1 5 10 15	
Ala Ala Gly Glu Ala Ala Lys Val Gly Gly Thr Gly Gly Ser Glu Lys	
20 25 30	
Ile Gly Asp Ala Asp Asn Asn Lys Gly Ala Val Ala Asp Ala Ser Ser	
35 40 45	
Val Asn Gly Ile Ala Asn Gly Ile Lys Gly Ile Val Asp Ala Ala Gly	
50 55 60	
Lys Ala Phe Gly Lys Asp Gly Ala Leu Ala Gly Val Ala Ala Ala Ala	
65 70 75 80	
Glu Asn Asp Asp Lys Lys Asp Ala Gly Lys Leu Phe Ala Gly Lys Asn	
85 90 95	
Gly Gly Ala Gly Ala Ala Asp Ala Ile Gly Lys Ala Ala Ala Ala Val	
100 105 110	
Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala	
115 120 125	
Gly Ala Ala Ala Asn Gln Ala Gly Lys Lys Ala Ala Asp Ala Lys Asn	
130 135 140	
Pro Ile Ala Ala Ala Ile Gly Thr Ala Asp Asp Gly Ala Glu Phe Lys	
145 150 155 160	
Asp Asp Met Lys Lys Ser Asp Asn Ile Ala Ala Ala Ile Val Leu Arg	
165 170 175	
Gly Val Ala Lys Asp Gly Lys Phe Ala Val Ala Asn Ala Asp Asp Asn	
180 185 190	

-continued

Lys Ala Ser Val Lys Ser Ala Val
195 200

<210> SEQ ID NO 72
<211> LENGTH: 592
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(591)

<400> SEQUENCE: 72

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aca 48
Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1 5 10 15

gct gct ggt gag gct gca aaa gtt ggt gct ggt ggt gct gat aag 96
Ala Ala Gly Glu Ala Ala Lys Val Gly Ala Gly Gly Ala Asp Lys
20 25 30

att ggg gat gct gct aat aat cag ggt gcg aag gct gat gag agc agt 144
Ile Gly Asp Ala Ala Asn Asn Gln Gly Ala Lys Ala Asp Glu Ser Ser
35 40 45

gtt aat gga att gca aag ggg ata aag ggg att gtt gat gct gct ggg 192
Val Asn Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly
50 55 60

aag gct ttt ggc aag gag ggt agt gcg ctg aag gat gtt gca aaa gtt 240
Lys Ala Phe Gly Lys Glu Gly Ser Ala Leu Lys Asp Val Ala Lys Val
65 70 75 80

gct gat gat gat aac aag gat gcg ggg aag ttg ttt gct ggt aat gct 288
Ala Asp Asp Asp Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Asn Ala
85 90 95

ggt ggt ggt gct ggt gct gat att gcg aag gcg gct gct gct gtt act 336
Gly Gly Gly Ala Gly Ala Asp Ile Ala Lys Ala Ala Ala Ala Val Thr
100 105 110

gcg gtt agt ggg gag cag ata ctg aaa gct att gtt gat gct gct ggt 384
Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Gly
115 120 125

gct gcg gat cag gcg ggt gca gct gct ggt gcg gct aag aat ccg att 432
Ala Ala Asp Gln Ala Gly Ala Ala Ala Gly Ala Ala Lys Asn Pro Ile
130 135 140

gcg gct gcg att ggg gct gat gct ggt gct gcg gag gag ttt aag gat 480
Ala Ala Ala Ile Gly Ala Asp Ala Gly Ala Ala Glu Glu Phe Lys Asp
145 150 155 160

gag atg aag aag agt gat aag att gct gcg gct att gtt ttg agg ggg 528
Glu Met Lys Lys Ser Asp Lys Ile Ala Ala Ala Ile Val Leu Arg Gly
165 170 175

gtg gct aag ggt gga aag ttt gct gtt gct gct aat gat gct gca aat 576
Val Ala Lys Gly Gly Lys Phe Ala Val Ala Ala Asn Asp Ala Ala Asn
180 185 190

gtg aag agt gct gtg g 592
Val Lys Ser Ala Val
195

<210> SEQ ID NO 73
<211> LENGTH: 197
<212> TYPE: PRT
<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 73

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr
1 5 10 15

Ala Ala Gly Glu Ala Ala Lys Val Gly Ala Gly Gly Gly Ala Asp Lys

-continued

20				25				30							
Ile	Gly	Asp	Ala	Ala	Asn	Asn	Gln	Gly	Ala	Lys	Ala	Asp	Glu	Ser	Ser
		35					40					45			
Val	Asn	Gly	Ile	Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	Asp	Ala	Ala	Gly
	50					55					60				
Lys	Ala	Phe	Gly	Lys	Glu	Gly	Ser	Ala	Leu	Lys	Asp	Val	Ala	Lys	Val
	65				70					75					80
Ala	Asp	Asp	Asp	Asn	Lys	Asp	Ala	Gly	Lys	Leu	Phe	Ala	Gly	Asn	Ala
				85					90					95	
Gly	Gly	Gly	Ala	Gly	Ala	Asp	Ile	Ala	Lys	Ala	Ala	Ala	Ala	Val	Thr
			100						105					110	
Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Asp	Ala	Ala	Gly
		115					120					125			
Ala	Ala	Asp	Gln	Ala	Gly	Ala	Ala	Ala	Gly	Ala	Ala	Lys	Asn	Pro	Ile
	130					135					140				
Ala	Ala	Ala	Ile	Gly	Ala	Asp	Ala	Gly	Ala	Ala	Glu	Glu	Phe	Lys	Asp
	145				150					155					160
Glu	Met	Lys	Lys	Ser	Asp	Lys	Ile	Ala	Ala	Ala	Ile	Val	Leu	Arg	Gly
				165					170					175	
Val	Ala	Lys	Gly	Gly	Lys	Phe	Ala	Val	Ala	Ala	Asn	Asp	Ala	Ala	Asn
			180					185					190		
Val	Lys	Ser	Ala	Val											
			195												

<210> SEQ ID NO 74

<211> LENGTH: 597

<212> TYPE: DNA

<213> ORGANISM: Borrelia afzelii

<220> FEATURE:

<221> NAME/KEY: CDS

<222> LOCATION: (1)..(597)

<400> SEQUENCE: 74

gag	agt	gct	ggt	gag	ggt	agc	gca	tgg	tta	gaa	gag	atg	ata	aca	48	
Glu	Ser	Ala	Val	Gly	Glu	Val	Ser	Ala	Trp	Leu	Glu	Glu	Met	Ile	Thr	
1			5					10					15			
gct	gct	agt	gag	gct	gct	aca	aag	ggt	ggt	act	ggt	ggt	act	ggt	ggt	96
Ala	Ala	Ser	Glu	Ala	Ala	Thr	Lys	Gly	Gly	Thr	Gly	Gly	Thr	Gly	Gly	
			20					25					30			
gat	agt	gaa	aag	att	ggg	gat	tct	gat	gct	aat	aat	ggt	gct	gta	gct	144
Asp	Ser	Glu	Lys	Ile	Gly	Asp	Ser	Asp	Ala	Asn	Asn	Gly	Ala	Val	Ala	
		35				40						45				
gat	gcg	agc	agt	ggt	aag	gag	att	gcg	aag	ggg	ata	aag	ggg	att	ggt	192
Asp	Ala	Ser	Ser	Val	Lys	Glu	Ile	Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	
	50					55					60					
gat	gct	gct	ggg	aag	gct	tgt	ggt	aag	gat	ggt	aat	gcg	ctg	aag	gat	240
Asp	Ala	Ala	Gly	Lys	Ala	Phe	Gly	Lys	Asp	Gly	Asn	Ala	Leu	Lys	Asp	
	65				70					75					80	
ggt	gca	gaa	ggt	gct	gat	gat	gag	gct	aac	gcg	gat	gcg	ggg	aag	ttg	288
Val	Ala	Glu	Val	Ala	Asp	Asp	Glu	Ala	Asn	Ala	Asp	Ala	Gly	Lys	Leu	
				85					90					95		
ttt	gct	ggt	aat	gct	ggt	aat	gct	gct	gct	gct	gac	ggt	gcg	aag	gcg	336
Phe	Ala	Gly	Asn	Ala	Gly	Asn	Ala	Ala	Ala	Ala	Asp	Val	Ala	Lys	Ala	
			100					105					110			
gct	ggt	gct	ggt	act	gcg	ggt	agt	ggg	gag	cag	ata	ctg	aaa	gct	att	384
Ala	Gly	Ala	Val	Thr	Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	
			115				120					125				
ggt	gat	gct	gct	ggt	gct	gcg	gat	cag	gcg	ggt	gca	aag	gct	gat	gcg	432

-continued

```

Val Asp Ala Ala Gly Ala Ala Asp Gln Ala Gly Ala Lys Ala Asp Ala
 130                               135                               140

gct aag aat ccg att gca gct gcg att ggg act aat gaa gct ggg gcg      480
Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Glu Ala Gly Ala
145                               150                               155                               160

gcg ttt aag gat gga atg aag aag aga aat gat aat att gct gcg gct      528
Ala Phe Lys Asp Gly Met Lys Lys Arg Asn Asp Asn Ile Ala Ala Ala
                               165                               170                               175

att gtt ttg agg ggg gtg gct aag agt gga aag ttt gct gtt gct gct      576
Ile Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala Val Ala Ala
                               180                               185                               190

gct gat gct ggt aag gcg aga                                          597
Ala Asp Ala Gly Lys Ala Arg
                               195

```

```

<210> SEQ ID NO 75
<211> LENGTH: 199
<212> TYPE: PRT
<213> ORGANISM: Borrelia afzelii

```

```

<400> SEQUENCE: 75

```

```

Glu Ser Ala Val Gly Glu Val Ser Ala Trp Leu Glu Glu Met Ile Thr
 1                               5                               10                               15

Ala Ala Ser Glu Ala Ala Thr Lys Gly Gly Thr Gly Gly Thr Gly Gly
 20                               25                               30

Asp Ser Glu Lys Ile Gly Asp Ser Asp Ala Asn Asn Gly Ala Val Ala
 35                               40                               45

Asp Ala Ser Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile Val
 50                               55                               60

Asp Ala Ala Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Lys Asp
 65                               70                               75                               80

Val Ala Glu Val Ala Asp Asp Glu Ala Asn Ala Asp Ala Gly Lys Leu
 85                               90                               95

Phe Ala Gly Asn Ala Gly Asn Ala Ala Ala Asp Val Ala Lys Ala
100                               105                               110

Ala Gly Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile
115                               120                               125

Val Asp Ala Ala Gly Ala Ala Asp Gln Ala Gly Ala Lys Ala Asp Ala
130                               135                               140

Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asn Glu Ala Gly Ala
145                               150                               155                               160

Ala Phe Lys Asp Gly Met Lys Lys Arg Asn Asp Asn Ile Ala Ala Ala
165                               170                               175

Ile Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala Val Ala Ala
180                               185                               190

Ala Asp Ala Gly Lys Ala Arg
195

```

```

<210> SEQ ID NO 76
<211> LENGTH: 621
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(621)

```

```

<400> SEQUENCE: 76

```

```

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg ata aca      48
Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr

```

-continued

1	5	10	15	
gct gct agt gag gct gca aaa gtt ggt gct ggt ggt gat gat aag att				96
Ala Ala Ser Glu Ala Ala Lys Val Gly Ala Gly Gly Asp Asp Lys Ile				
	20	25	30	
ggg gat tct gct aat aat ggt gct gta gct gat gcg ggc agt gtt aag				144
Gly Asp Ser Ala Asn Asn Gly Ala Val Ala Asp Ala Gly Ser Val Lys				
	35	40	45	
gga att gcg aag ggg ata aag ggg att gtt gat gct gct ggg aag gct				192
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala				
	50	55	60	
ttt ggt aag gag ggt gat gcg ctg aag gat gtt gca aaa gtt gct gat				240
Phe Gly Lys Glu Gly Asp Ala Leu Lys Asp Val Ala Lys Val Ala Asp				
	65	70	75	80
gag aat ggg gat aac aag gat gcg ggg aag ttg ttt gct ggt gag aat				288
Glu Asn Gly Asp Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Glu Asn				
	85	90	95	
ggt aat gct ggt ggt gct gct gat gct gac att gcg aag gcg gct gct				336
Gly Asn Ala Gly Gly Ala Ala Asp Ala Asp Ile Ala Lys Ala Ala Ala				
	100	105	110	
gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt gag				384
Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Glu				
	115	120	125	
gct gct ggt gct ggt gat gca gct aat cag gcg ggt aag aag gct gat				432
Ala Ala Gly Ala Gly Asp Ala Ala Asn Gln Ala Gly Lys Lys Ala Asp				
	130	135	140	
gag gct aag aat ccg att gcg gct gcg att ggg act gat gat gct ggg				480
Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala Gly				
	145	150	155	160
gcg gcg ttt ggt cag gat gat atg aag aag aga aat gat aat att gct				528
Ala Ala Phe Gly Gln Asp Asp Met Lys Lys Arg Asn Asp Asn Ile Ala				
	165	170	175	
gcg gct att gtt ttg agg ggg gtg gct aag ggt gga aag ttt gct gtt				576
Ala Ala Ile Val Leu Arg Gly Val Ala Lys Gly Gly Lys Phe Ala Val				
	180	185	190	
gct aat gct gct aat gat agt aag gcg agt gtg aag agt gct gtg				621
Ala Asn Ala Ala Asn Asp Ser Lys Ala Ser Val Lys Ser Ala Val				
	195	200	205	

<210> SEQ ID NO 77

<211> LENGTH: 207

<212> TYPE: PRT

<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 77

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr																				
1				5						10									15	
Ala Ala Ser Glu Ala Ala Lys Val Gly Ala Gly Gly Asp Asp Lys Ile				20						25									30	
Gly Asp Ser Ala Asn Asn Gly Ala Val Ala Asp Ala Gly Ser Val Lys				35						40									45	
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala				50						55									60	
Phe Gly Lys Glu Gly Asp Ala Leu Lys Asp Val Ala Lys Val Ala Asp				65						70									75	80
Glu Asn Gly Asp Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Glu Asn				85						90										95
Gly Asn Ala Gly Gly Ala Ala Asp Ala Asp Ile Ala Lys Ala Ala Ala				100						105										110

-continued

Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Glu
 115 120 125

Ala Ala Gly Ala Gly Asp Ala Ala Asn Gln Ala Gly Lys Lys Ala Asp
 130 135 140

Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala Gly
 145 150 155 160

Ala Ala Phe Gly Gln Asp Asp Met Lys Lys Arg Asn Asp Asn Ile Ala
 165 170 175

Ala Ala Ile Val Leu Arg Gly Val Ala Lys Gly Gly Lys Phe Ala Val
 180 185 190

Ala Asn Ala Ala Asn Asp Ser Lys Ala Ser Val Lys Ser Ala Val
 195 200 205

<210> SEQ ID NO 78
 <211> LENGTH: 459
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(459)

<400> SEQUENCE: 78

gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag ata ata aca 48
 Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Ile Ile Thr
 1 5 10 15

gct act ggg aag gct ttt ggt aag gat ggt aat gcg ctg gca ggt gtt 96
 Ala Thr Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Ala Gly Val
 20 25 30

gca aaa gtt gct gat gat gag gct aac gcg gat gcg ggg aag ttg ttt 144
 Ala Lys Val Ala Asp Asp Glu Ala Asn Ala Asp Ala Gly Lys Leu Phe
 35 40 45

gct ggt gag aat ggt aat gct ggt gct gct gcg att ggg aag gcg gct 192
 Ala Gly Glu Asn Gly Asn Ala Gly Ala Ala Ala Ile Gly Lys Ala Ala
 50 55 60

gct gct gtt act gcg gtt agt ggg gag cag ata ctg aaa gct att gtt 240
 Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 65 70 75 80

gat gct gct ggt ggt gcg gct cag gtg ggt gct ggt gct ggt gcg gct 288
 Asp Ala Ala Gly Gly Ala Ala Gln Val Gly Ala Gly Ala Gly Ala Ala
 85 90 95

acg aat ccg att gca gct gcg att ggg gct gct ggt gat ggt gcg gat 336
 Thr Asn Pro Ile Ala Ala Ala Ile Gly Ala Ala Gly Asp Gly Ala Asp
 100 105 110

ttt ggt aag gat gag atg aag aag aga aat gat aag att gct gcg gct 384
 Phe Gly Lys Asp Glu Met Lys Lys Arg Asn Asp Lys Ile Ala Ala Ala
 115 120 125

att gtt ttg agg ggg gtg gct aag gat gga aag ttt gct gct gct gct 432
 Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala Ala
 130 135 140

aat gat agt aag gcg agt gtg aag agt 459
 Asn Asp Ser Lys Ala Ser Val Lys Ser
 145 150

<210> SEQ ID NO 79
 <211> LENGTH: 153
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 79

Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Ile Ile Thr
 1 5 10 15

-continued

Ala Thr Gly Lys Ala Phe Gly Lys Asp Gly Asn Ala Leu Ala Gly Val
 20 25 30

Ala Lys Val Ala Asp Asp Glu Ala Asn Ala Asp Ala Gly Lys Leu Phe
 35 40 45

Ala Gly Glu Asn Gly Asn Ala Gly Ala Ala Ala Ile Gly Lys Ala Ala
 50 55 60

Ala Ala Val Thr Ala Val Ser Gly Glu Gln Ile Leu Lys Ala Ile Val
 65 70 75 80

Asp Ala Ala Gly Gly Ala Ala Gln Val Gly Ala Gly Ala Gly Ala Ala
 85 90 95

Thr Asn Pro Ile Ala Ala Ala Ile Gly Ala Ala Gly Asp Gly Ala Asp
 100 105 110

Phe Gly Lys Asp Glu Met Lys Lys Arg Asn Asp Lys Ile Ala Ala Ala
 115 120 125

Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Ala Ala
 130 135 140

Asn Asp Ser Lys Ala Ser Val Lys Ser
 145 150

<210> SEQ ID NO 80
 <211> LENGTH: 612
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(612)

<400> SEQUENCE: 80

gct gtg gag agt gct gtt gat gag gtt agc aag tgg tta gaa gag atg 48
 Ala Val Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met
 1 5 10 15

ata aca gct gct gat gct gct gct gct aaa gtt ggc gat gct ggt ggt 96
 Ile Thr Ala Ala Asp Ala Ala Ala Ala Lys Val Gly Asp Ala Gly Gly
 20 25 30

ggt gct gat aag att ggg gat gtt ggt gct gct aat aag ggt gcg aag 144
 Gly Ala Asp Lys Ile Gly Asp Val Gly Ala Ala Asn Lys Gly Ala Lys
 35 40 45

gct gat gcg agc agt gtt aag gag att gcg aag ggg ata aag ggg att 192
 Ala Asp Ala Ser Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile
 50 55 60

gtt gat gct gct ggg aag gct ttt ggt ggt gat gcg ctg aag gat gtt 240
 Val Asp Ala Ala Gly Lys Ala Phe Gly Gly Asp Ala Leu Lys Asp Val
 65 70 75 80

aaa gct gct ggt gat gat aac aag gag gca ggg aag ttg ttt gct ggt 288
 Lys Ala Ala Gly Asp Asp Asn Lys Glu Ala Gly Lys Leu Phe Ala Gly
 85 90 95

gct aat ggt aat gct ggt gct aat gct gct gct gct gat gac att gcg 336
 Ala Asn Gly Asn Ala Gly Ala Asn Ala Ala Ala Asp Asp Ile Ala
 100 105 110

aag gcg gct ggt gct gtt agt gcg gtt agt ggg gag cag ata ctg aaa 384
 Lys Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys
 115 120 125

gct att gtt gag gcg gct ggt gct gcg gat cag gcg ggt gta aag gct 432
 Ala Ile Val Glu Ala Ala Gly Ala Ala Asp Gln Ala Gly Val Lys Ala
 130 135 140

gag gag gct aag aat ccg att gca gct gcg att ggg act gat gat gct 480
 Glu Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala
 145 150 155 160

-continued

```

ggt gcg gcg gag ttt ggt gag aat gat atg aag aag aat gat aat att 528
Gly Ala Ala Glu Phe Gly Glu Asn Asp Met Lys Lys Asn Asp Asn Ile
      165                      170                      175

gct gcg gct att gtt ttg agg ggg gtg gct aag agt gga aag ttt gct 576
Ala Ala Ala Ile Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala
      180                      185                      190

gct aat gct aat gat gct ggt aag aag gag agt gtg 612
Ala Asn Ala Asn Asp Ala Gly Lys Lys Glu Ser Val
      195                      200

```

```

<210> SEQ ID NO 81
<211> LENGTH: 204
<212> TYPE: PRT
<213> ORGANISM: Borrelia afzelii

```

```

<400> SEQUENCE: 81

```

```

Ala Val Glu Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met
 1          5          10          15

Ile Thr Ala Ala Asp Ala Ala Ala Ala Lys Val Gly Asp Ala Gly Gly
 20          25          30

Gly Ala Asp Lys Ile Gly Asp Val Gly Ala Ala Asn Lys Gly Ala Lys
 35          40          45

Ala Asp Ala Ser Ser Val Lys Glu Ile Ala Lys Gly Ile Lys Gly Ile
 50          55          60

Val Asp Ala Ala Gly Lys Ala Phe Gly Gly Asp Ala Leu Lys Asp Val
 65          70          75          80

Lys Ala Ala Gly Asp Asp Asn Lys Glu Ala Gly Lys Leu Phe Ala Gly
 85          90          95

Ala Asn Gly Asn Ala Gly Ala Asn Ala Ala Ala Ala Asp Asp Ile Ala
 100         105         110

Lys Ala Ala Gly Ala Val Ser Ala Val Ser Gly Glu Gln Ile Leu Lys
 115         120         125

Ala Ile Val Glu Ala Ala Gly Ala Ala Asp Gln Ala Gly Val Lys Ala
 130         135         140

Glu Glu Ala Lys Asn Pro Ile Ala Ala Ala Ile Gly Thr Asp Asp Ala
 145         150         155         160

Gly Ala Ala Glu Phe Gly Glu Asn Asp Met Lys Lys Asn Asp Asn Ile
 165         170         175

Ala Ala Ala Ile Val Leu Arg Gly Val Ala Lys Ser Gly Lys Phe Ala
 180         185         190

Ala Asn Ala Asn Asp Ala Gly Lys Lys Glu Ser Val
 195         200

```

```

<210> SEQ ID NO 82
<211> LENGTH: 603
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(603)

```

```

<400> SEQUENCE: 82

```

```

aag agt gct gtg gat gag gct agc aag tgg tta gaa gag atg ata aca 48
Lys Ser Ala Val Asp Glu Ala Ser Lys Trp Leu Glu Glu Met Ile Thr
 1          5          10          15

gct gct ggt gag gct gct aca aag ggt ggt act ggt gaa gct agc gaa 96
Ala Ala Gly Glu Ala Ala Thr Lys Gly Gly Thr Gly Glu Ala Ser Glu
 20          25          30

aag att ggg gat gtt ggt gat aat aat cat ggt gct gta gct gat gcg 144

```

-continued

Lys	Ile	Gly	Asp	Val	Gly	Asp	Asn	Asn	His	Gly	Ala	Val	Ala	Asp	Ala		
		35					40					45					
gac	agt	ggt	aag	ggg	att	gcg	aag	ggg	ata	aag	ggg	att	ggt	gat	gct		192
Asp	Ser	Val	Lys	Gly	Ile	Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	Asp	Ala		
	50					55				60							
gct	ggg	aag	gct	ttt	ggt	aag	gat	ggt	gcg	ctg	aag	gat	ggt	gca	gct		240
Ala	Gly	Lys	Ala	Phe	Gly	Lys	Asp	Gly	Ala	Leu	Lys	Asp	Val	Ala	Ala		
	65				70				75					80			
gct	gct	ggt	gat	gag	gct	aac	aag	gat	gcg	ggg	aag	ttg	ttt	gct	ggt		288
Ala	Ala	Gly	Asp	Glu	Ala	Asn	Lys	Asp	Ala	Gly	Lys	Leu	Phe	Ala	Gly		
				85					90					95			
cag	gat	ggt	ggt	ggt	gct	gat	ggt	gac	att	gcg	aag	gcg	gct	gct	gct		336
Gln	Asp	Gly	Gly	Gly	Ala	Asp	Gly	Asp	Ile	Ala	Lys	Ala	Ala	Ala	Ala		
			100					105					110				
ggt	act	gcg	ggt	agt	ggg	gag	cag	ata	ctg	aaa	gct	att	ggt	gag	gct		384
Val	Thr	Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Glu	Ala		
		115					120					125					
gct	ggt	gat	aag	gct	aat	cag	gtg	ggt	gta	aag	gct	gct	ggt	gcg	gct		432
Ala	Gly	Asp	Lys	Ala	Asn	Gln	Val	Gly	Val	Lys	Ala	Ala	Gly	Ala	Ala		
	130					135				140							
acg	aat	ccg	att	gca	gct	gcg	att	ggg	act	gat	gat	gat	aat	gcg	gcg		480
Thr	Asn	Pro	Ile	Ala	Ala	Ala	Ile	Gly	Thr	Asp	Asp	Asp	Asn	Ala	Ala		
	145				150					155				160			
gcg	ttt	gat	aag	gat	gag	atg	aag	aag	agt	aat	gat	aag	att	gct	gcg		528
Ala	Phe	Asp	Lys	Asp	Glu	Met	Lys	Lys	Ser	Asn	Asp	Lys	Ile	Ala	Ala		
			165						170				175				
gct	att	ggt	ttg	agg	ggg	gtg	gct	aag	gat	gga	aag	ttt	gct	gct	aat		576
Ala	Ile	Val	Leu	Arg	Gly	Val	Ala	Lys	Asp	Gly	Lys	Phe	Ala	Ala	Asn		
			180				185						190				
gct	aat	gat	aat	agt	aag	gcg	agt	gtg									603
Ala	Asn	Asp	Asn	Ser	Lys	Ala	Ser	Val									
		195					200										

<210> SEQ ID NO 83
 <211> LENGTH: 201
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 83

Lys	Ser	Ala	Val	Asp	Glu	Ala	Ser	Lys	Trp	Leu	Glu	Glu	Met	Ile	Thr		
1				5					10					15			
Ala	Ala	Gly	Glu	Ala	Ala	Thr	Lys	Gly	Gly	Thr	Gly	Glu	Ala	Ser	Glu		
		20						25					30				
Lys	Ile	Gly	Asp	Val	Gly	Asp	Asn	Asn	His	Gly	Ala	Val	Ala	Asp	Ala		
		35					40					45					
Asp	Ser	Val	Lys	Gly	Ile	Ala	Lys	Gly	Ile	Lys	Gly	Ile	Val	Asp	Ala		
	50					55					60						
Ala	Gly	Lys	Ala	Phe	Gly	Lys	Asp	Gly	Ala	Leu	Lys	Asp	Val	Ala	Ala		
	65				70					75				80			
Ala	Ala	Gly	Asp	Glu	Ala	Asn	Lys	Asp	Ala	Gly	Lys	Leu	Phe	Ala	Gly		
				85					90					95			
Gln	Asp	Gly	Gly	Gly	Ala	Asp	Gly	Asp	Ile	Ala	Lys	Ala	Ala	Ala	Ala		
			100					105					110				
Val	Thr	Ala	Val	Ser	Gly	Glu	Gln	Ile	Leu	Lys	Ala	Ile	Val	Glu	Ala		
		115					120					125					
Ala	Gly	Asp	Lys	Ala	Asn	Gln	Val	Gly	Val	Lys	Ala	Ala	Gly	Ala	Ala		
	130					135					140						
Thr	Asn	Pro	Ile	Ala	Ala	Ala	Ile	Gly	Thr	Asp	Asp	Asp	Asn	Ala	Ala		

-continued

145	150	155	160	
Ala Phe Asp Lys Asp Glu Met Lys Lys Ser Asn Asp Lys Ile Ala Ala				
	165	170	175	
Ala Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Asn				
	180	185	190	
Ala Asn Asp Asn Ser Lys Ala Ser Val				
	195	200		
<210> SEQ ID NO 84				
<211> LENGTH: 249				
<212> TYPE: DNA				
<213> ORGANISM: Borrelia afzelii				
<220> FEATURE:				
<221> NAME/KEY: CDS				
<222> LOCATION: (1)..(249)				
<400> SEQUENCE: 84				
aag agt gct gtg gat gag gtt agc aag tgg tta gaa gag atg ata aca				48
Lys Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr				
1	5	10	15	
gct gct agt gat gct gct aca aag ggt ggt act ggt gaa gct agc gaa				96
Ala Ala Ser Asp Ala Ala Thr Lys Gly Gly Thr Gly Glu Ala Ser Glu				
	20	25	30	
aag att ggg gat tct gat gct aat aag ggt gct ggt gct ggg gcg gcg				144
Lys Ile Gly Asp Ser Asp Ala Asn Lys Gly Ala Gly Ala Gly Ala Ala				
	35	40	45	
ttt ggt gag aat gat atg aag aag aga aat gat aat att gct gca gct				192
Phe Gly Glu Asn Asp Met Lys Lys Arg Asn Asp Asn Ile Ala Ala Ala				
	50	55	60	
att gtt ttg agg ggg gtg gct aag gat gga aag ttt gct gtt aag gag				240
Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Val Lys Glu				
65	70	75	80	
gat tat tga				249
Asp Tyr				

<210> SEQ ID NO 85
 <211> LENGTH: 82
 <212> TYPE: PRT
 <213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 85

Lys Ser Ala Val Asp Glu Val Ser Lys Trp Leu Glu Glu Met Ile Thr				
1	5	10	15	
Ala Ala Ser Asp Ala Ala Thr Lys Gly Gly Thr Gly Glu Ala Ser Glu				
	20	25	30	
Lys Ile Gly Asp Ser Asp Ala Asn Lys Gly Ala Gly Ala Gly Ala Ala				
	35	40	45	
Phe Gly Glu Asn Asp Met Lys Lys Arg Asn Asp Asn Ile Ala Ala Ala				
	50	55	60	
Ile Val Leu Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Val Lys Glu				
65	70	75	80	
Asp Tyr				

<210> SEQ ID NO 86
 <211> LENGTH: 537
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia afzelii
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(537)

-continued

<400> SEQUENCE: 86

```

atg gaa aaa ata gaa aaa ttt aaa aac aaa tgt caa cat aaa cta caa      48
Met Glu Lys Ile Glu Lys Phe Lys Asn Lys Cys Gln His Lys Leu Gln
1           5           10           15

cat aaa cta atc gta tta gta tca aca ctt tgc tat ata aac aat aaa      96
His Lys Leu Ile Val Leu Val Ser Thr Leu Cys Tyr Ile Asn Asn Lys
           20           25           30

aat aaa aaa tat tca caa agc aac atc ctt tat tat ttt aat gaa aat      144
Asn Lys Lys Tyr Ser Gln Ser Asn Ile Leu Tyr Tyr Phe Asn Glu Asn
           35           40           45

tta aaa aga aat ggg caa acc cct att aaa ata aaa aca tta caa aac      192
Leu Lys Arg Asn Gly Gln Thr Pro Ile Lys Ile Lys Thr Leu Gln Asn
           50           55           60

tat ctt tat aaa ctg gaa aaa gaa ttt gaa gta aca act aat tat tat      240
Tyr Leu Tyr Lys Leu Glu Lys Glu Phe Glu Val Thr Thr Asn Tyr Tyr
65           70           75           80

aaa cac ttg ggg gtt aat tgt gga acc gaa att tac tat aaa ctt aaa      288
Lys His Leu Gly Val Asn Cys Gly Thr Glu Ile Tyr Tyr Lys Leu Lys
           85           90           95

tat caa aaa caa aaa tgc tat cat aaa ata aac caa tat ttt aaa aag      336
Tyr Gln Lys Gln Lys Cys Tyr His Lys Ile Asn Gln Tyr Phe Lys Lys
           100          105          110

aaa aaa gaa att aaa ttt aac tta aga gta agt gca ttt ttt aat aaa      384
Lys Lys Glu Ile Lys Phe Asn Leu Arg Val Ser Ala Phe Phe Asn Lys
           115          120          125

aaa cac tca aaa aaa ggg agt gta gaa tta aag gaa tgt aat aat aat      432
Lys His Ser Lys Lys Gly Ser Val Glu Leu Lys Glu Cys Asn Asn Asn
           130          135          140

aat aat aat aaa gag aaa gaa aca tcc caa aaa att gaa att tta caa      480
Asn Asn Asn Lys Glu Lys Glu Thr Ser Gln Lys Ile Glu Ile Leu Gln
145          150          155          160

aca aaa gtc tat gcc aaa aaa tgt aaa ttt ttg aca aac tac tat act      528
Thr Lys Val Tyr Ala Lys Lys Cys Lys Phe Leu Thr Asn Tyr Tyr Thr
           165          170          175

aaa att tta
Lys Ile Leu
537

```

<210> SEQ ID NO 87

<211> LENGTH: 179

<212> TYPE: PRT

<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 87

```

Met Glu Lys Ile Glu Lys Phe Lys Asn Lys Cys Gln His Lys Leu Gln
1           5           10           15

His Lys Leu Ile Val Leu Val Ser Thr Leu Cys Tyr Ile Asn Asn Lys
           20           25           30

Asn Lys Lys Tyr Ser Gln Ser Asn Ile Leu Tyr Tyr Phe Asn Glu Asn
           35           40           45

Leu Lys Arg Asn Gly Gln Thr Pro Ile Lys Ile Lys Thr Leu Gln Asn
           50           55           60

Tyr Leu Tyr Lys Leu Glu Lys Glu Phe Glu Val Thr Thr Asn Tyr Tyr
65           70           75           80

Lys His Leu Gly Val Asn Cys Gly Thr Glu Ile Tyr Tyr Lys Leu Lys
           85           90           95

Tyr Gln Lys Gln Lys Cys Tyr His Lys Ile Asn Gln Tyr Phe Lys Lys
           100          105          110

Lys Lys Glu Ile Lys Phe Asn Leu Arg Val Ser Ala Phe Phe Asn Lys

```

-continued

115	120	125
Lys His Ser Lys Lys Gly Ser Val Glu Leu Lys Glu Cys Asn Asn Asn 130	135	140
Asn Asn Asn Lys Glu Lys Glu Thr Ser Gln Lys Ile Glu Ile Leu Gln 145	150	155
Thr Lys Val Tyr Ala Lys Lys Cys Lys Phe Leu Thr Asn Tyr Tyr Thr 165	170	175
Lys Ile Leu		

<210> SEQ ID NO 88
 <211> LENGTH: 2775
 <212> TYPE: DNA
 <213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 88

```

cggaaatcaa gccacctaaa acaacttccc aaaagtttct caaaaaatat tatattcagc      60
agtaaattct ataagtcatt aattatttaa tactattcaa cagtaaattc tataagtcatt      120
taattattta atactattca gcagtaaatt ctataagtca ttaattattt aatactattc      180
agcagtaaat tctataagtc attaattatt taatactatt cagcagtaaa ttctataagt      240
cattaattat ttaatactat tcagcagtaa attctataag tcattaatta ttaataacta      300
ttcagcagta aattctataa gtcattaatt caattaggta acggattctt agatgtattc      360
acctcttttg gtggattagt tgcagatgca ttggggttta aagctgatcc aaaaaaatct      420
gatgtaaaaa cttattttga atctctagct aaaaaattag aagaaacaaa agatggttta      480
actaagttgt ccaaaggtaa tgacgggatg actggaaagg ctggatgatgc tgggtggggct      540
gggtggggcg ctagtgctgc aggtggcgct ggtgggattg agggcgctat aacagagatt      600
agcaaatggg tagatgatat ggcaaaagct gctgcggaag ctgcaagtgc tgctactggg      660
aatgcagcaa ttggggatgt tgtaaatggg aatgggtggg cagcaaaagg tggatgatgcg      720
gagagtgtta atgggattgc taaggggata aaggggattg ttgatgctgc tgagaaggct      780
gatgcgaagg aaggggaagt ggatgtggct ggtgatgctg gtggggctgg tgggtggcgct      840
ggtgctgcag gtggcgctgg tgggattgag ggcgctataa cagagattag caaatggtta      900
gatgatatgg caaaagctgc tgcggttgct gcaagtgctg caagtgctgc tactggtaat      960
gcagcaattg gggatgttgt taatggtaat gatggagcag caaaaggtgg tgatgcggcg     1020
agtgttaatg ggattgctaa ggggataaag gggattgttg atgctgctga gaaggctgat     1080
gcgaaggaag ggaagtggga tgtggctggg gatgctggtg agggtaacaa ggatgctggg     1140
aagctgtttg tgaagaagaa tgctggatgat gaggggtggg aagcaaatga tgctgggaag     1200
gctgctgctg cggttgctgc tgtagtggg gagcagatat taaaagcgat tgttgatgct     1260
gctgaggggt atgataagca gggtaagaag gctgcggatg ctacaaatcc gattgaggcg     1320
gctattgggg gtgcggatgc ggggtgctaat gctgaggcgt ttaataagat gaagaaggat     1380
gatcagattg ctgctgctat ggttctgagg ggaatggcta aggatgggca gtttgctttg     1440
aaggatgatg ctgctgctca tgaagggact gtaagaatg ctggtgatat ggcaaaggcc     1500
gctgcggaag ctgcaagtgc tgcaagtgct gctactggta gtacaacgat tggagatggt     1560
gttaagagtg gtgaggcaaa agatgggtgat gcggcgagtg ttaatgggat tgctaagggg     1620
ataaagggga ttgttgatgc tgctgagaag gctgatgcga aggaagggaa gttggatgtg     1680
gctggtgctg ctggtacgac taacgtgaat gttgggaagt tgtttgtgaa gaataatggt     1740
    
```

-continued

aatgaggggtg	gtgatgcaag	tgatgctggg	aaagctgctg	ctgcggttgc	tgctgttagt	1800
ggggagcaga	tattaaaagc	gattgttgat	gctgctaaag	atggtgataa	gcaggggggtt	1860
actgatgtaa	aggatgctac	aatccgatt	gaggcggcta	ttgggggtac	aatgataat	1920
gatgctgceg	cgtttgctac	tatgaagaag	gatgatcaga	ttgctgctgc	tatggttctg	1980
aggggaatgg	ctaaggatgg	gcagtttgct	ttgaaggatg	atgctgctaa	ggatggatgat	2040
aaaacggggg	ttgctgceg	tgctgaaaat	ccgattgacg	cggctattgg	gggtgceggt	2100
gctgatgctg	cggcgtttaa	taaggagggg	atgaagaagg	atgatcagat	tgctgctgct	2160
atggttctga	ggggaatggc	taaggatggg	cagtttgctt	tgacgaataa	tgctgctgct	2220
catgaaggga	ctgtaagaa	tgctgttgat	atggcaaaag	ctgctgcegt	tgctgcaagt	2280
gctgctactg	gcaatgcagc	aattggggat	gttgttaaga	gtaatggtgg	agcagcagca	2340
aaagtggtg	atgcggcgag	tgtaaatggg	attgctaagg	ggataaaggg	gattgttgat	2400
gctgctgaga	aggctgatgc	gaaggaaggg	aagtggatg	tggtggtgc	tgctggtgaa	2460
actaacaagg	atgctgggaa	gttgtttgct	aagaagaatg	gtgatgatgg	tggtgatgca	2520
ggtgatgctg	ggaaggctgc	tgctgcegtt	gctgctgtta	gtggggagca	gatattaaaa	2580
gcgattgttg	atgctgctaa	agatggatg	aagacggggg	ttactgatgt	aaaggatgct	2640
acaaatccga	ttgacgcggc	tattgggggg	agtgcggatg	ctaagtctga	ggcgtttgat	2700
aagatgaaga	aggatgatca	gattgctgct	gctatggttc	tgaggggaat	ggctaaggat	2760
gggcagtttg	ctttg					2775

<210> SEQ ID NO 89

<211> LENGTH: 2075

<212> TYPE: DNA

<213> ORGANISM: Borrelia garinii

<400> SEQUENCE: 89

ataaagggga	ttgttgatgc	tgctgagaag	gctgatgcca	aggaagggaa	gttggatgtg	60
gctggtgatg	ctggtgaaac	taacaaggat	gctgggaagt	tgtttgtaa	gaacaatggg	120
aatgaggggtg	gtgatgcaga	tgatgctggg	aaggctgctg	ctgcggttgc	tgctgttagt	180
ggggagcaga	tattaaaagc	gattgttgat	gctgctaaag	gtggtgataa	gacgggtaag	240
aataatgtga	aggatgctga	aatccgatt	gaggcggcta	ttgggagtag	tgccgatgct	300
gatgctgceg	cgtttaataa	ggaggggatg	aagaaggatg	atcagattgc	tgctgctatg	360
gttctgaggg	gaatggctaa	ggatgggcag	ttgctttg	cgaatgatgc	tgctgctcat	420
gaagggactg	ttaagaatgc	tggtgggagt	gcaacaata	agaccgttgt	tgctttggct	480
aacttggttc	gaaagaccgt	gcaagctggg	ttgaagaagg	ttggggatgt	tgtaagaat	540
agtgaggcaa	aagatggtga	tgccggcag	gttaatggga	ttgctaaggg	gataaagggg	600
attgttgatg	ctgctgagaa	ggctgatg	aaggaaggga	agttggatgt	ggctggtgct	660
gctggtgaaa	ctaacaagga	tgctgggaag	ttgtttgta	agaagaataa	tgaggggtgg	720
gaagcaaatg	atgctgggaa	ggctgctgct	gcggttctg	ctgttagtgg	ggagcagata	780
ttaaagcga	ttgttgatgc	tgctaaggat	ggtgatgata	agcagggtaa	gaaggctgag	840
gatgctacaa	atccgattga	cgcggctatt	gggggtgcag	gtgcgggtgc	taatgctgct	900
gcggcgttta	ataatatgaa	gaaggatgat	cagattgctg	ctgctatggt	tctgagggga	960
atggctaagg	atgggcagtt	tgctttgacg	aataatgctc	ataactaatca	taaggggact	1020
gttaagaatg	ctgttgatat	gacaaaagct	gctgcggttg	ctgcaagtgc	tgcaagtgct	1080

-continued

```

gctactggta atgcagcaat tggggatggt gttaatggta atgatggagc agcaaaaggt 1140
ggtgatgccc cgagtgttaa tgggattgct aaggggataa aggggattgt tgatgctgct 1200
gagaaggctg atgcgaagga agggaagttg aatgtggctg gtgctgctgg tgctgagggt 1260
aacgaggctg ctgggaagct gtttgtgaag aagaatgctg gtgatcatgg tggggaagca 1320
ggtgatgctg ggagggctgc tgctgcccgtt gctgctgtta gtggggagca gatattaata 1380
gcgattgttg atgctgctaa ggatgggtgg gataagcagg gtaagaaggc tgaggatgct 1440
gaaaatccga ttgacgcggc tattggggagt acgggtgccc atgataatgc tgctgaggcg 1500
tttgctacta tgaagaagga tgatcagatt gctgctgcta tggttctgag gggaaatggct 1560
aaggatgggc agtttgcttt gaaggatgct gctcatgata atcataaggg gactgttaag 1620
aatgctgttg atataataaa ggctactgcg gttgctgcaa gtgctgctac tggtagtaca 1680
acgattgggg atgttgtaa gaatgggtgag gcaaaaagggtg gtgaggcgaa gactgttaat 1740
gggattgcta aggggataaa ggggattggt gatgctgctg gaaaggctga tgccaaggaa 1800
gggaagttga atgtggctgg tgctgctggt gagggtaacg aggctgctgg gaagctgttt 1860
gtgtaaatta ctataggatt agaactagtg tacgatatga gtcctttggt tattttgcag 1920
ctgctaataa atttgaaata agtgaagtta aaattgcgga tgtaaatgga acacatttta 1980
ttgctacaaa agagaaagaa atattatatg attcacttga ttttaagggt cgtggaaaaa 2040
tatttgaaat aacttcaaag cgaatgttta agctt 2075

```

```

<210> SEQ ID NO 90
<211> LENGTH: 552
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(552)

```

<400> SEQUENCE: 90

```

gaa ggg act gtt aag aat gct gtt gat atg gca aaa gct gct gcg gtt 48
Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Ala Val
1 5 10 15
gct gca agt gct gct act ggc aat gca gca att ggg gat gtt gtt aag 96
Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Lys
20 25 30
agt aat ggt gga gca gca gca aaa ggt ggt gat gcg gcg agt gtt aat 144
Ser Asn Gly Gly Ala Ala Ala Lys Gly Gly Asp Ala Ala Ser Val Asn
35 40 45
ggg att gct aag ggg ata aag ggg att gtt gat gct gct gag aag gct 192
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala
50 55 60
gat gcg aag gaa ggg aag ttg gat gtg gct ggt gct gct ggt gaa act 240
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Glu Thr
65 70 75 80
aac aag gat gct ggg aag ttg ttt gtg aag aag aat ggt gat gat ggt 288
Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn Gly Asp Asp Gly
85 90 95
ggt gat gca ggt gat gct ggg aag gct gct gct gcg gtt gct gct gtt 336
Gly Asp Ala Gly Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val
100 105 110
agt ggg gag cag ata tta aaa gcg att gtt gat gct gct aaa gat ggt 384
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly
115 120 125
gat aag acg ggg gtt act gat gta aag gat gct aca aat ccg att gac 432

```


-continued

```

Asp Lys Thr Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Asp
 130          135          140
gcg gct att ggg ggg agt gcg gat gct aat gct gag gcg ttt gat aag      480
Ala Ala Ile Gly Gly Ser Ala Asp Ala Asn Ala Glu Ala Phe Asp Lys
145          150          155          160
atg aag aag gat gat cag att gct gct gct atg gtt ctg agg gga atg      528
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met
          165          170          175
gct aag gat ggg cag ttt gct ttg      552
Ala Lys Asp Gly Gln Phe Ala Leu
          180

```

```

<210> SEQ ID NO 91
<211> LENGTH: 184
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

```

```

<400> SEQUENCE: 91

```

```

Glu Gly Thr Val Lys Asn Ala Val Asp Met Ala Lys Ala Ala Ala Val
 1          5          10          15
Ala Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Lys
          20          25          30
Ser Asn Gly Gly Ala Ala Ala Lys Gly Gly Asp Ala Ala Ser Val Asn
          35          40          45
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala
          50          55          60
Asp Ala Lys Glu Gly Lys Leu Asp Val Ala Gly Ala Ala Gly Glu Thr
          65          70          75          80
Asn Lys Asp Ala Gly Lys Leu Phe Val Lys Lys Asn Gly Asp Asp Gly
          85          90          95
Gly Asp Ala Gly Asp Ala Gly Lys Ala Ala Ala Ala Val Ala Ala Val
          100          105          110
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly
          115          120          125
Asp Lys Thr Gly Val Thr Asp Val Lys Asp Ala Thr Asn Pro Ile Asp
          130          135          140
Ala Ala Ile Gly Gly Ser Ala Asp Ala Asn Ala Glu Ala Phe Asp Lys
          145          150          155          160
Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg Gly Met
          165          170          175
Ala Lys Asp Gly Gln Phe Ala Leu
          180

```

```

<210> SEQ ID NO 92
<211> LENGTH: 420
<212> TYPE: DNA
<213> ORGANISM: Borrelia garinii
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(420)

```

```

<400> SEQUENCE: 92

```

```

ata aag ggg att gtt gat gct gct gag aag gct gat gcg aag gaa ggg      48
Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala Lys Glu Gly
 1          5          10          15
aag ttg gat gtg gct ggt gat gct ggt gaa act aac aag gat gct ggg      96
Lys Leu Asp Val Ala Gly Asp Ala Gly Glu Thr Asn Lys Asp Ala Gly
          20          25          30
aag ttg ttt gtg aag aac aat ggt aat gag ggt ggt gat gca gat gat      144

```


-continued

```

aagctgtttg tgaagaagaa tgctgggtgat catggtgggtg aagcaggtga tgctggggagg 360
gctgctgctg cggttgctgc tgtagtgagg gagcagatat taaaagcgat tgtagtgct 420
gctaaggatg gtggtgataa gcagggtaag aaggctgagg atgctgaaaa tccgattgac 480
gcggtattg ggagtacggg tgccgatgat aatgctgctg aggcgtttgc tactatgaag 540
aaggatgata agattgctgc tgctatggtt ctgaggggaa tggctaagga tgggcagttt 600
gctttgaagg atgctgctca tgataatcat ctgcagccaa gcttaattag ctgagcttgg 660
actcctgttg atagatccag taatgacctc agaactccat ctggatttgt tcagaacgct 720
cggttgcccgc cgggcgtttt ttattgggtga gaatccaagc tagcttgccg agattttcag 780
gagctaagga agctaaaatg gagaaaaaat cactggatat accaccgttg atatatccca 840
atggcatcgt aaagaacatt ttgaggcatt tcagtcagtt gctcaatgta cctataacca 900
gaccgttcag ctggatatta cggccttttt aaagaccgta ag 942

```

```

<210> SEQ ID NO 95
<211> LENGTH: 217
<212> TYPE: PRT
<213> ORGANISM: Borrelia garinii

```

```

<400> SEQUENCE: 95

```

```

Met Arg Gly Ser His His His His His His Gly Ser Lys Gly Thr Val
1           5           10          15
Lys Asn Ala Val Asp Met Thr Lys Ala Ala Ala Val Ala Ala Ser Ala
20          25          30
Ala Ser Ala Ala Thr Gly Asn Ala Ala Ile Gly Asp Val Val Asn Gly
35          40          45
Asn Asp Gly Ala Ala Lys Gly Gly Asp Ala Ala Ser Val Asn Gly Ile
50          55          60
Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Glu Lys Ala Asp Ala
65          70          75          80
Lys Glu Gly Lys Leu Asn Val Ala Gly Ala Ala Gly Ala Glu Gly Asn
85          90          95
Glu Ala Ala Gly Lys Leu Phe Val Lys Lys Asn Ala Gly Asp His Gly
100         105         110
Gly Glu Ala Gly Asp Ala Gly Arg Ala Ala Ala Ala Val Ala Ala Val
115         120         125
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Asp Ala Ala Lys Asp Gly
130         135         140
Gly Asp Lys Gln Gly Lys Lys Ala Glu Asp Ala Glu Asn Pro Ile Asp
145         150         155         160
Ala Ala Ile Gly Ser Thr Gly Ala Asp Asp Asn Ala Ala Glu Ala Phe
165         170         175
Ala Thr Met Lys Lys Asp Asp Gln Ile Ala Ala Ala Met Val Leu Arg
180         185         190
Gly Met Ala Lys Asp Gly Gln Phe Ala Leu Lys Asp Ala Ala His Asp
195         200         205
Asn His Leu Gln Pro Ser Leu Ile Ser
210         215

```

```

<210> SEQ ID NO 96
<211> LENGTH: 663
<212> TYPE: DNA
<213> ORGANISM: Borrelia afzelii

```

-continued

<400> SEQUENCE: 96

```

atgagaggat cgcacaccca tcaccatcac ggatccaaga gtgctgtgga tgaggctagc    60
aagtggttag aagagatgat aacagctgct ggtgaggctg ctacaaaggg tggtagctgt    120
gaagctagcg aaaagattgg ggatggttgg gataataatc atggtgctgt agctgatgcg    180
gacagtgtta aggggattgc gaaggggata aaggggattg ttgatgctgc tgggaaggct    240
tttgtaagg atggtgctgt gaaggatggt gcagctgctg ctggtgatga ggctaacaag    300
gatgcgggga agttggttgc tggtcaggat ggtggtggtg ctgatggtga cattgcgaag    360
gcgctgctg ctgttactgc ggttagtggg gacagatac tgaagctat tgttgaggct    420
gctggtgata aggctaatac ggtgggtgta aaggctgctg gtgcggctac gaatccgatt    480
gcagctgcga ttgggactga tgatgataat gcggcggcgt ttgataagga tgagatgaag    540
aagagtaatg ataagattgc tgcggctatt gtttgaggg ggggtggctaa ggatggaaag    600
tttctgcta atgctaatag taatagtaag gcgagtgtgc tgcagccaag cttaattagc    660
tga                                                                                   663

```

<210> SEQ ID NO 97

<211> LENGTH: 220

<212> TYPE: PRT

<213> ORGANISM: Borrelia afzelii

<400> SEQUENCE: 97

```

Met Arg Gly Ser His His His His His His Gly Ser Lys Ser Ala Val
1           5           10           15
Asp Glu Ala Ser Lys Trp Leu Glu Glu Met Ile Thr Ala Ala Gly Glu
20           25           30
Ala Ala Thr Lys Gly Gly Thr Gly Glu Ala Ser Glu Lys Ile Gly Asp
35           40           45
Val Gly Asp Asn Asn His Gly Ala Val Ala Asp Ala Asp Ser Val Lys
50           55           60
Gly Ile Ala Lys Gly Ile Lys Gly Ile Val Asp Ala Ala Gly Lys Ala
65           70           75           80
Phe Gly Lys Asp Gly Ala Leu Lys Asp Val Ala Ala Ala Ala Gly Asp
85           90           95
Glu Ala Asn Lys Asp Ala Gly Lys Leu Phe Ala Gly Gln Asp Gly Gly
100          105          110
Gly Ala Asp Gly Asp Ile Ala Lys Ala Ala Ala Ala Val Thr Ala Val
115          120          125
Ser Gly Glu Gln Ile Leu Lys Ala Ile Val Glu Ala Ala Gly Asp Lys
130          135          140
Ala Asn Gln Val Gly Val Lys Ala Ala Gly Ala Ala Thr Asn Pro Ile
145          150          155          160
Ala Ala Ala Ile Gly Thr Asp Asp Asp Asn Ala Ala Ala Phe Asp Lys
165          170          175
Asp Glu Met Lys Lys Ser Asn Asp Lys Ile Ala Ala Ala Ile Val Leu
180          185          190
Arg Gly Val Ala Lys Asp Gly Lys Phe Ala Ala Asn Ala Asn Asp Asn
195          200          205
Ser Lys Ala Ser Val Leu Gln Pro Ser Leu Ile Ser
210          215          220

```

<210> SEQ ID NO 98

<211> LENGTH: 26

-continued

<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 98

cggaattcac tcgccttact attatc 26

<210> SEQ ID NO 99
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 99

cgggatccga gaggctgtt gatgaggtt 29

<210> SEQ ID NO 100
<211> LENGTH: 35
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 100

cgggatccaa gaggctgtg gatgaggcta gcaag 35

<210> SEQ ID NO 101
<211> LENGTH: 35
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 101

ttctgcagca cactgcctt actattatca ttagc 35

<210> SEQ ID NO 102
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 102

cgggatccgc tggtgggagt ygcaac 26

<210> SEQ ID NO 103
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
Primer

<400> SEQUENCE: 103

aactgcagat tatcatgagc agcatccttc 30

<210> SEQ ID NO 104
<211> LENGTH: 33
<212> TYPE: DNA

-continued

<213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

<400> SEQUENCE: 104

cgggatccaa ggggactgtt aagaatgctg ttg 33

<210> SEQ ID NO 105
 <211> LENGTH: 34
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

<400> SEQUENCE: 105

ttctgcagat gattatcatg agcagcatcc ttca 34

<210> SEQ ID NO 106
 <211> LENGTH: 17
 <212> TYPE: DNA
 <213> ORGANISM: *Borrelia burgdorferi*

<400> SEQUENCE: 106

tgagggggct attaagg 17

<210> SEQ ID NO 107
 <211> LENGTH: 12
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
 Primer

<400> SEQUENCE: 107

ccggaattcc gg 12

I claim:

1. A recombinant polypeptide molecule comprising at least 12 contiguous amino acids of SEQ ID NO: 40 immobilized on a solid support.

2. The recombinant polypeptide of claim 1, wherein the recombinant polypeptide comprises at least 13 contiguous amino acids of SEQ ID NO: 40.

3. The recombinant polypeptide of claim 1, wherein the recombinant polypeptide comprises at least 20 contiguous amino acids of SEQ ID NO: 40.

4. The recombinant polypeptide of claim 1, wherein the recombinant polypeptide comprises at least 35 contiguous amino acids of SEQ ID NO: 40.

5. The recombinant polypeptide of claim 1, wherein the recombinant polypeptide comprises at least 50 contiguous amino acids of SEQ ID NO: 40.

40 6. The recombinant polypeptide of claim 1, wherein the recombinant polypeptide comprises the sequence of SEQ ID NO: 40.

7. A method of assaying for *Borrelia* infection comprising:

45 (a) contacting a sample obtained from a subject with an isolated polypeptide, said isolated polypeptide being immobilized on a surface and comprising at least 12 contiguous amino acids of SEQ ID NO: 40; and

50 (b) determining whether immunologic binding occurs between the isolated polypeptide and an antibody in the sample, wherein immunologic binding is indicative of *Borrelia* infection.

8. The method of claim 7, wherein said contacting step comprises performing an ELISA assay.

* * * * *